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BY

ALFRED C. LANE

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1911

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ERRATA.

Page 25, 11th line from bottom read "slicken-siding" for "slicken-sliding."
Page 27, 7th line from top read "Chamberlin" for "Chamberlain."
Page 35, 6th line from bottom read "glomeroporphyritic" for "glomeroporphyric."
Page 35, 15th line from bottom read "an" for "and."
Page 52, 7th line from bottom read "anamesite" for "anametite."
Page 53, 5th line from top read "has" for "had."
Page 61, middle of page read "enstatite" for "enstalite."
Page 73, 12th line from top read "apatite" for "patite."
Page 73, 13th line from top read "Minnesotare" for "Minnesotiare."
Page 76, 2nd line from top read "Becke" for "Becker."
Page 89, 4th line from top read "G. L. Heath" for "G. H. Heath."
Page 93, near bottom read "gravelly" for "gravel."
Page 98, 18th line from bottom, read "F. E." for "F. W."
Page 104, 2nd line from bottom read "are in" for "is."
Page 105, caption, read "minerals" for "numerals."
Page 117, 11th line from bottom read "Sec." for "Ces."
Page 131, foot-note, read "fits" for "fit."
Page 133, description of figure read "panidiomorphism" for "panidiomorplin."
Page 156, foot-note, read "49-51" for "49-50."
Page 190, 8th line from top, read "Bohemia" for "Bohemian."
Page 203, middle of page, read "Medora foot" for "Medora foote."
Page 210, 16th line from bottom read "porphyritic" for "porphyrite."
Page 257, middle of page read "horizon" for "horizine."
Page 275, 2nd line from top, read "M. 7. 5. S. d. 58-333."
Page 276, middle of page read "Philip S. Smith."
Page 314, 13th line from top read "gray trap."
Page 350, 2nd line from bottom read "conglomerate" for "conglomerated."
Page 371, between 4th and 5th line of §10, insert "belts of the Old Colony is given along the eastern edge of the Calu-."
Page 400, 11th line from top read "mosaic" for "mosiac."
Page 406, 11th line from bottom read "distorted" for "distended."
Page 429, 9th line from bottom read " $\frac{416}{731 - 416}$ "
Page 434, 16th line from top dele " = ."
Page 452, 12th line from top read "62-324?" for "am. -324? 62."
Page 457, 10th line from top read "Marvine's" for "Marvin's."
Page 457, 12th line from bottom read "oligoclase" for "oliogclase."
Page 485, 2nd line from bottom read "Honnold" for "Honhold."

VOLUME II.

Page 505, 6th line from bottom read "Dr. L. L. Hubbard."
Page 518, foot-note, read "XXII" for "XXI."
Page 521, 2nd line from bottom read "to sea level."
Page 531, Elm River drill hole 1, read "T. 52 N., R. 36 W." for "T. 32 N., R. 36 W."
Page 541, Location of Hole 8 read "825′ W." for "825′ N."
Page 566, middle of page read "(N. 6° E.)" for "(N. 60° E.)"
Page 566, foot-note read "curves" for "cures."
Page 573, Transfer 10 + from end of line 16 to end of line 19.
Page 582, 2nd line from top read "1-1.5" for "1-0.5."
Page 610, 19th line from bottom read "mine" for "mines."
Page 635, 24th line from bottom read "bed rock surface" for "bed rock margin."
Page 644, 3rd line from bottom read "Bytownite" for "Bytounite."
Page 654, 12th line from bottom read "1.75 × 1.24" for "1.95 × 1.24."
Page 660, 15th line from bottom read "CO_2" for "Ce."
Page 660, 3rd line from bottom read "Conglomerate 18" for "Conglomerate 17."
Page 701, 21st line from bottom read "distinctly" for "dictinctly."
Page 723, 18th line from bottom insert "for" after word "diorite."
Page 683, 10th line from top insert word "base" after word "pumiceous."
Page 756, 8th line from bottom insert "inches of" after "four."
Page 783, 3rd line from bottom read "H. L." for "H. H."
Page 810, 1st line of foot-note, insert semicolon after "result."
Page 818, 3rd line from bottom read "no salt" for "no shaft."
Page 825, 7th line from bottom read "Bee" for "B."
Page 833, 8th line from top read "M. L. Holm" for "J. W. Holm."
Page 844, 5th line from bottom read "Van't Hoff" for "Van Hoff."
Page 847, 3rd line from bottom, dele the apostrophe after "Stokes."
Page 881, 10th line from bottom read "had" for "have."
Page 888, 19th line from top read "valleys" for "valeys."
Page 914, 10th line from bottom read "percussion" for "precussion."
Page 938, 15th line from bottom read "Brauns" for "Braums."
Page 939, 1st line of foot-note read "capital" for "capitol."

LETTER OF TRANSMITTAL.

Lansing, Mich., Nov. 1, 1911.

To the Honorable, the Board of Geological and Biological Survey of the State of Michigan:

Gov. Chase S. Osborn, President.
Hon. D. M. Ferry, Jr., Vice President.
Hon. L. L. Wright, Secretary.

Gentlemen—I have the honor to transmit for publication as a part of the report for 1909 of the Board of Geological and Biological Survey, Publication 6, Geological Series 4, in two volumes, a contribution to the geological survey of the State.

Very respectfully,
R. C. ALLEN,
Director.

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FOREWORD.

May I take the opportunity to express my obligations to Mr. A. H. Meuche for help rendered since he left the Survey and to Mr. R. C. Allen, my successor as State Geologist of Michigan, as well as to all those who both on and off the Survey have done so much to help me. I want to thank Mr. Allen in particular for aid in finishing up the illustrations, as well as for his willingness to help me in every way, and especially for permission to announce that while the cross-sections are on a rather small scale, engineers who have need of them on the original scale can make arrangements with the Survey office to obtain blue prints.

It is one of the necessary inconveniences of publishing that by the time a thing is out, it is out of date. I regret that I have not been able to give to the able work of Van Hise and Leith in Monograph 52 of the U. S. G. S. (the report on the geology of the Lake Superior region) the attention which it deserves. The text of this report (part of that for the year 1909, it will be noted) was written before that appeared. I have inserted a few necessary references in the foot-notes, while reading proof, mainly to indicate points where our views diverge. But I have not thought I ought to burden an already bulky report by augmentation. I am glad to say we now practically agree as to the stratigraphy of the Keweenawan and other *facts*, and these will, in due time, speak for themselves.

Very respectfully,
ALFRED C. LANE.

CHAPTER I.

A POPULAR DESCRIPTION.

§ 1. INTRODUCTION.

This first chapter is intended to be a short account of the whole subject put in language that may be understood by people who have taken no course in geology. It is based on an article for the Lake Superior Mining Institute, but I have tried to fit it for an even wider circle of readers,—the miner, the normal school student, and the business man. And I have tried at the same time to convey as much information as possible. In such a chapter the arguments for the various conclusions can not be given and it must be largely a statement of results, for the results may have to be derived from the most refined and technical research.

In my studies of the copper bearing rocks I have received favors from mining men from one end of the range to the other and I take occasion here to express my thanks to C. A. Wright, W. W. Stockly and A. H. Sawyer of the Keweenaw Copper Co., W. J. Penhallegon, who took a very intelligent interest in the matters over which he had charge for the Calumet and Hecla around the Delaware: D. D. Scott at the Phoenx; Dr. L. L. Hubbard, my friend and co-worker in science, and A. Formis who have charge of the Ojibway; Fred Smith and W. F. Hartman at the Mohawk and Wolverine; Capt. James S. Chynoweth; Jas. McNaughton and E. S. Grierson, F. W. Ridley, G. H. Heath, J. B. Cooper, J. Pollard, and many others at the Calumet; R. M. Edwards, Mat. M. Dennis, Charles B. Lawton, R. H. Shields, A. C. Burrage, Norman W. Haire, W. J. Uren, Jas. E. Richards, F. W. Denton, R. R. Seeber, Reg. C. Pryor, Mr. Hotchkiss, of the Adventure, J. M. Wilcox, E. Fenner Douglas, Geo. Hooper, and R. S. Schultz.

§ 2. THE LAKE SUPERIOR BASIN.

The State of Michigan is divided by Lake Michigan into two peninsulas (Fig. 1), which may be likened to the right and left hands of the State. In fact the resemblance is so striking that the district east of Saginaw Bay has long been known as the

Thumb of the Lower Peninsula. But just as the Lower Peninsula lies between Lakes Michigan and Huron with Point Aux Barques projecting as a thumb into Lake Huron, so the Upper Peninsula lies between Lakes Michigan and Superior (Fig. 1). Upon this point occur the famous mines of native copper, which

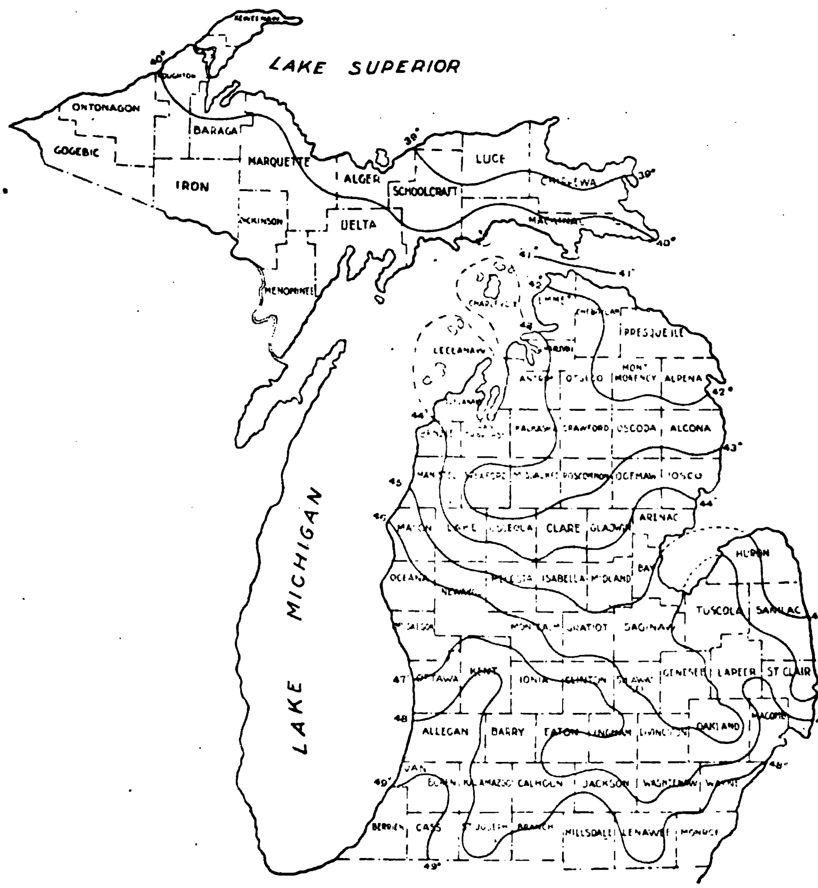


Fig. 1. Outline map of Michigan showing the "Thumbs;" also the mean annual temperatures. See Chapter VI, § 2.

may perhaps be classed as the richest and the deepest in the world. The rocks in which they occur surround Lake Superior continuously at the west end and patches are found at intervals all around it. They consist mainly of alternate layers of reddish sandstones and pebble beds, that is, conglomerates and layers of once molten lavas known as felsite, trap and amygdaloid. These beds dip toward the lake from all sides and individual beds

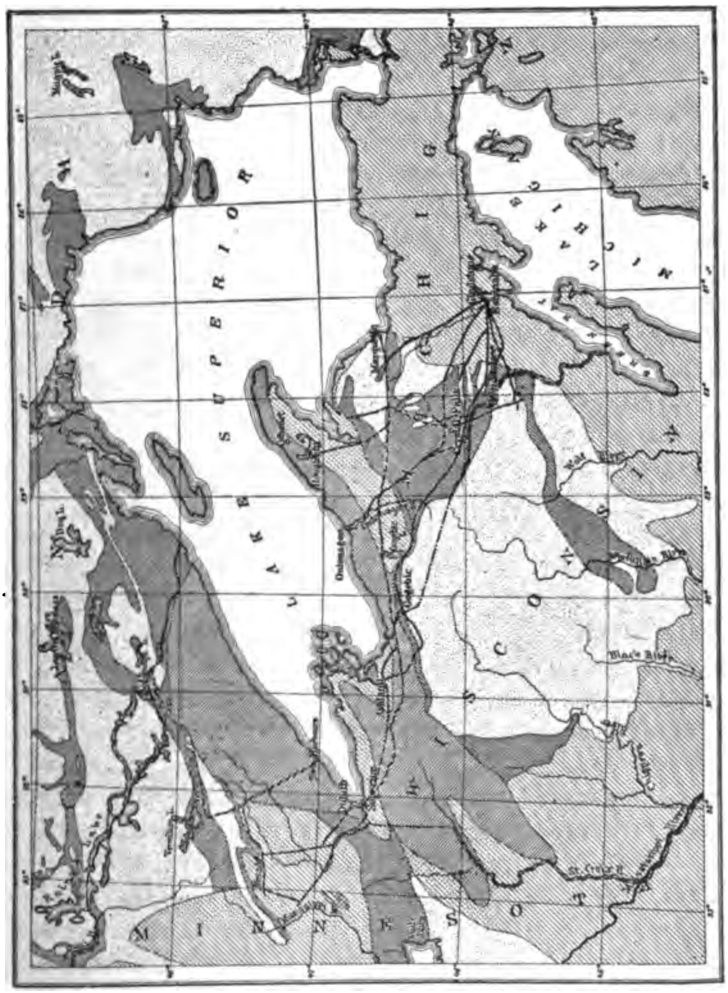


Fig. 2. Lake Superior region. Stippled areas are perhaps Pre-Huronian, those heavily lined down to the left are Huronian, down to the right are Keweenawan; Post Keweenawan is lightly lined down to the left. After Macco, Zeitschrift for praktische Geologie, 1904, p. 379.

can be shown to dip down, pass beneath it, and re-appear on the other side.

Lake Superior is about 412 miles long, and has an area of 31,200 square miles. The greatest depth is 1,008 feet and most of the lake is over 500 feet deep. Its average breadth is about 76 miles and since its depth is from one to two-tenths of a mile, it can be shown that it is a real, though slight, concavity in the round of the earth's surface, for the curvature of the round earth in a distance of 80 miles would mean that the level curve of the water would be about one-tenth of a mile above a straight line drawn from side to side. Thus the downward curve of the bottom of the Lake Superior basin is greater than the natural upward curve of the water surface. But if the bottom of Lake Superior is a downward curve, much more so must be the earth's crust passing beneath it. It is important to remember this, for if a downward bend is formed in the earth's crust it will not be easy to reverse it, any more than it is easy to reverse a crease in a piece of paper. So we are not surprised to find that the Lake Superior region seems to have remained a basin (or synclinal) from away back in geological history.

Accordingly, the beds to the northwest of the Lake dip to the southeast, and those to the south dip northward.

On the north and on the south of this basin-shaped (synclinal) downbend, are upbends, bosses, shields or anticlinals, as they have been called. These upbends have largely been worn away, exposing cores of granite. This granite appears south of Bessemer and Ironwood, and again in the Huron mountains. Intermixed and around these cores of granite come first a series of dark green rocks, in which the mineral hornblende is very conspicuous. These are the Keewatin rocks.

Next come the series of Huronian rocks in which our Michigan iron mines are located (Fig. 4). Like the Keweenawan rocks, the Huronian rocks on the north and south sides of Lake Superior are similar. For instance the Iron Range of Gogebic Lake corresponds to rocks about Port Arthur. Overlapping these there is a fringe of the copper bearing or Keweenawan rocks, which on the south side of Lake Superior are exposed at intervals from Silver mountain, which lies south of the head of Keweenaw Bay, past the south end of Lake Gogebic. On the north side they are found along the north shore of Lake Superior from Duluth to beyond Port Arthur. The succession of rocks is given in more detail in Figure 4, and is described in a later chapter.

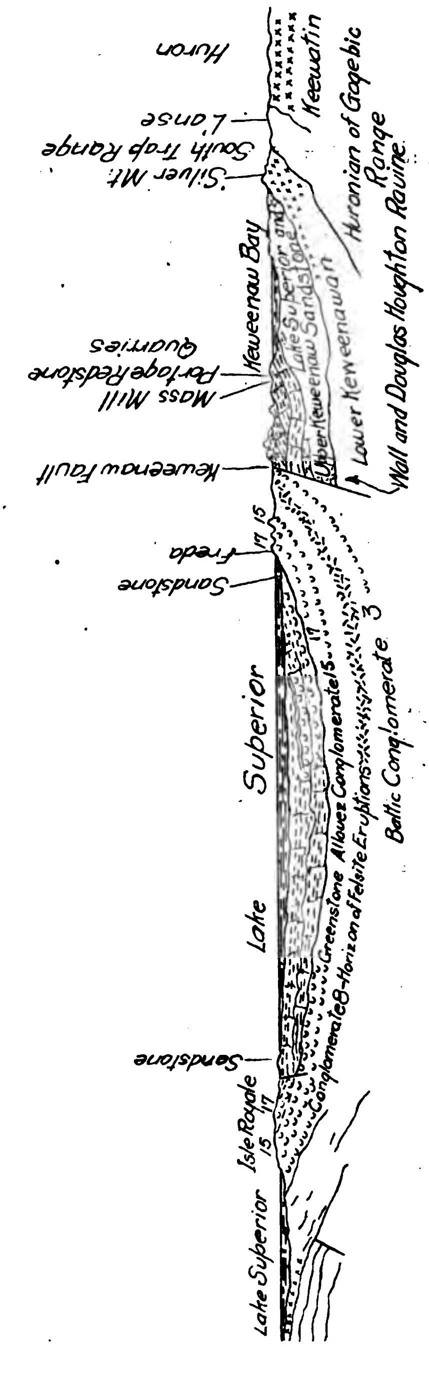


Fig. 3. Cross section through Lake Superior from the Huron Mountains to Port Arthur. After Mines and Minerals.

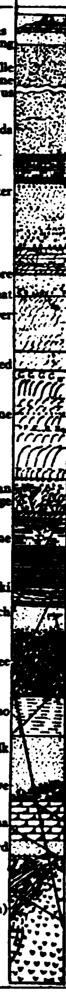
System	Series Name	Formation Name	Columnar Section	Thickness	Character of Rocks
Ordovician		St. Peter		0 to 75	*Sandstone;* white, waterbearing, in hollows of Calciferous dolomite, but absent often
		Calciferous		255 to 180	Buff and bluish dolomites often sandy, with dolomitic white sandstones.
	Neo-Cambrian Saratogan (Potsdam)	Lake Superior: Munising		200	*Sandstone;* white or light, waterbearing.
		Jacobsville Redstone		0 to 1500+ (4000?)	*Sandstone:* red and brown and striped with streaks of red clay shale, conglomeritic where it laps upon older formations.
		Hiatus		not drawn to	scale, the relation of the Freda to the Lake Superior Sandstone being uncertain, probably one formation.
	Upper Keweenawan, perhaps	Freda		(900+)?	*Sandstone:* red, with some felsitic and basic débris, and salt water.
Cambrian or Primordial	Mio-Cambrian	Nonesuch		350 to 600	*Shales:* dark, fissile beds, with dark basic fragments, and products of decomposition of lavas copper-bearing.
	Keweenawan	Copper Harbor: Outer		1000 to 3500	*Conglomerate:* very heavy, red, with large rounded bowlders of all lower formations, including jaspilitic iron ores, agate amygdules, gabbro aplites, etc.
		Lake Shore		1800 to 400	*Traps:* basaltic lavas, and at least one—the "Middle"—conglomerate.
		Great		2200 to 340	*Conglomerate:* very heavy, like the outer conglomerate.
		Eagle River		2300 to 1417	*Group* of basic lava flows, with *frequent* beds of sediment, Marvine's (c).
	Lower Keweenawan, perhaps eo-Cambrian	Ashbed		1496 to 2400± (50 sediment)	*Group* of basic lavas of the "ashbed" type with scoriaceous sediment and only 50 feet or so of conglomerate. Locally felsites.
		Central Mine		3823 to 25000 r (480 sediment)	*Group:* mainly of lavas of the augitic ophite type, with infrequent sediments. At the top is the "Mesnard epidote" and just beneath the heaviest flow, over 1,000 feet thick at times known as the Greenstone. Under this is the Allouez conglomerate, Marvine's No. 15. No. 13 is the Calumet and Hecla conglomerate or lode. The Kearsarge Lode is shortly above 9.
		Bohemian Range		? to 9500+ (500 sediment)	*Group:* mainly of basic lavas, but with intrusive and effusive felsites and coarse labradorite porphyrites; also intrusive diabase dikes and gabbro and gabbro aplites.
Huronian	Animikean neo-Huronian	Michigamme		1000 to 4000	*Slates:* black and graphitic, and graywacke slates, passing into graywacke arkoses, and quartzites; metamorphosed into staurolite, chiastolite, garnet, and other mica schists and phyllites.
		Bijiki		300 to 800	*Iron formation or schist:* slates with cherty carbonate and soft ore.
		Goodrich		0 to 400+	*Quartzite:* with conglomerate base, and above quartzite or red and green flags, also volcanic material.
	Mio-Huronian	Negaunee		1000±	*Iron formation:* cherty carbonates, altered to jaspilites, etc., with effusives and intrusives altering to hornblende schists and amphibolites.
		Siamo		600±	*Slates:* graywackes and arkoses and volcanics.
		Ajibik		700±	*Quartzite.*
		Wewe		300±	*Slate:* black largely.
	Eo-Huronian	Kona		600±	*Dolomite:* with siliceous cherty and slaty (schistose) bands.
		Mesnard		250±	*Quartzite:* conglomerate and arkose.
Keewatin		(Marinescan)		1000+	Greenstone schists, amphibolites, hornblende schists, sericite schists or crushed felsites, rarely ellipsoidal greenstones and slates and jaspilites, very largely cut by granites, the Laurentian, and numerous other classes of injections.

Fig. 4. Geological Column about Lake Superior. After Journal of Geology, and Fig. 2. Report for 1908.

§ 3. THE KEWEENAW FAULT.

The center of this basin has been crowded out of place and lifted up. Slow contraction of the earth causing compression of the outer layer of the crust may have produced such a stress as to spring it up (Fig. 5a), or it may have been lifted up on the back of some vast sill of molten rock thrusting its way in beneath (Fig. 5b). Such a great inserted mass (batholite) of heavy rock (gabbro) forms the basal member of the Keweenawan series in Minnesota and in Michigan near the Bessemer poor farm[1] is a similar basal intrusive sheet of gabbro. The latter is not so well exposed as the one in Minnesota. The lines of fracture along which beds have been thus displaced are known as faults (F'F of

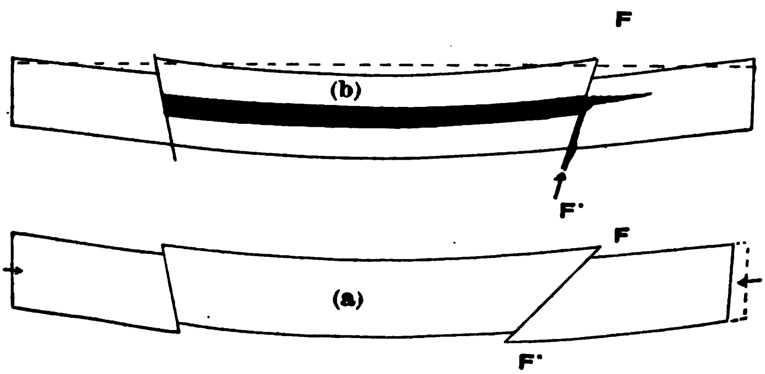


Fig. 5. Figures illustrating two possible explanations of the Keweenaw Fault, the lower (a) formation by compression; the upper (b) formation by the intrusion of a great gabbro sill.

Figure 5). Faults are not really straight although they are generally drawn as straight lines, nor are they always inclined at the same angle at every point. Though at times they are marked at the surface by a single narrow line which may be followed by a narrow seam of red clay, known to miners as fluccan, they are frequently characterized by a broad belt of shattered rock.

The great crack or fault in Michigan runs from Bete Gris Bay on Keweenaw Point southwestward past the north end of Lake Gogebic.

Thus going west from the Huron mountains we pass over flat lying sandstone (the Jacobsville sandstone) around the head of Keweenaw Bay, at Baraga, and near the Mass mill, which belongs above the copper bearing rock. Then we come to a great fault, on the northwest side of which the country is higher and the

[1]Annual report for 1906, p. 488.

rocks are uptilted so as to bring lower rocks, the copper bearing rocks, into view. These beds dip at first steeply, then more gradually northward to the lake. They are matched on the other side by similar beds on Isle Royale, which have steep dips with felsite at the north margin of the island as Keweenaw Point has on its south margin. The backbone of Isle Royale and that of Keweenaw Point is the same lava flow. The former is fringed on the south side by sandstone, while on Keweenaw Point sandstones occur near the various mill sites at Freda.

One reason for thinking that this great fault which bounds the copper range on the south is not merely due to intrusion, but in part to some long, slow action, like the shrinkage of the earth, is that there seems to have been motion along it for ages. Not so very far from it at Limestone mountain (in Sections 23 and 24, T. 51 N., R. 35 W., and again in Section 7 northeast) Paleozoic strata as late as the Niagara are caught and preserved in a fold in the Lake Superior sandstone, which along the line of the fault is disturbed from its normally nearly horizontal position. A picturesque instance of this is the Wall ravine not far north of Lake Linden, which, as well as the more noted Douglass Houghton ravine and falls, is north of and close to the electric line from Calumet to Lake Linden. A mile or two south of the College of Mines a number of ravines also show the fault, and the same region shows indications of faulting before as well as after the deposition of the Lake Superior sandstone, in the overlap of this sandstone upon the upturned copper range. Pebbles of lower beds of the Keweenawan series are also found in the higher conglomerates of the same formation, showing that the uplift began in Keweenawan time, and yet the fault line must have been a center of disturbance ages later.

Such a line of weakness when once formed naturally remains a line of weakness. Hobbs has shown that earthquakes follow the same lines of weakness again and again.

There is another way of looking at the faulting. The Keweenaw and previous formations show great overflows of molten rock from the earth's interior. The granite areas of the Huron mountains show great dikes of these lavas which have been thrust in and congealed. We therefore may easily see that if the lavas came from beneath Lake Superior there would be a tendency for the crust above to slump and perhaps for the sides to come together to fill the void thus left.

There are other main faults like the Keweenawan fault, nota-

bly one on the south side of the Porcupine mountain range, and others described by Lawson around Port Arthur.

§ 4. OTHER CRACKING.

With this uplift naturally came a good deal of other fracturing of the rock, splinter faults we might call them, and all this disturbance may have had a good deal to do with setting up and guiding the circulation of the waters that laid down the copper. Some people think that the copper was introduced into the formations at this time, but the writer thinks that it was only collected together into workable deposits.

The amount of uplift differs in various places and in some of them rather suddenly. While around the Calumet mine the beds dip 41 degrees or less, in the vicinity of Hancock and Houghton the dip is nearer 56 degrees, and a few miles farther south in the mines of the Copper Range Co. on the Baltic lode it is about 70 degrees. Numerous data on dip will be found in Chapter V.

There are many fractures running across the formation. The following figure shows a few of those along the Gogebic range, and how the range is by them broken up into blocks.

Further references to these fractures will be found on consulting the index. See, for instance, the fractures on the Wyoming and Manitou properties. Sometimes the beds are only slightly displaced and the fracture is marked merely by a seam in many instances filled with some white mineral like calcite or quartz. The pinkish sawdust-like laumontite, the lead colored copper ore, chalcocite (or glance), native copper, and brass colored copper arsenides like Mohawkite occur in the seams. Along some fractures the displacement is greater but in most instances it is only a short distance. Hardly a mine is without cross-fissures, yet it can not be said that in general the mines are richer next to them in the main Keweenaw range.

Usually, but not always, at a fissure running northward a bed running, or as it is called, striking east or northeast and dipping north under the lake is found to the right as one follows it across the fissure from west to northeast or east, as though the beds had on that side been thrown to the south or downward. This is well marked in the last two fissures of Figure 6. However, in following a bed across what seems on the surface to be such a fracture the bed may never be lost entirely but simply deflected suddenly from its course on entering a belt of much disturbed ground, filled with innumerable minor fractures coated with clay

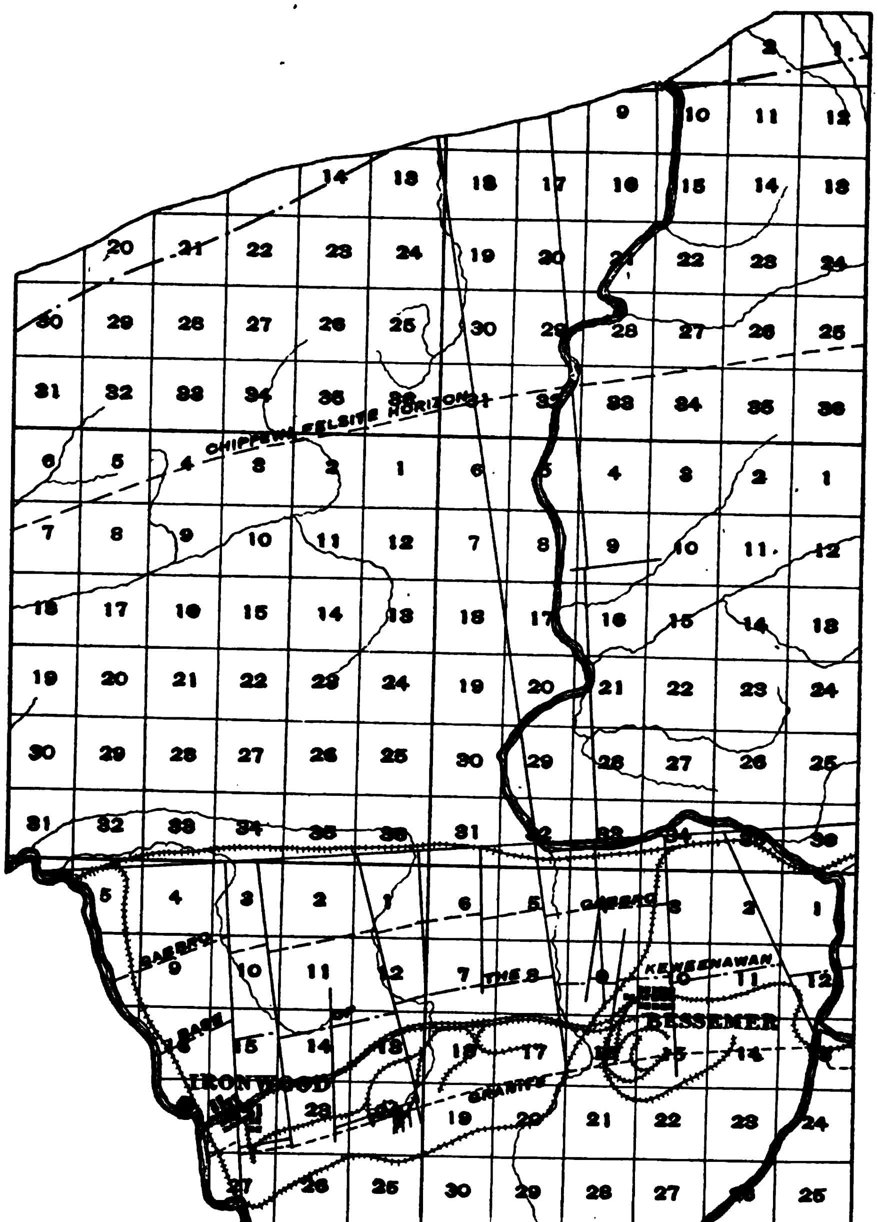


Fig. 6. Cross fractures north of the Gogebic Range. (From Report for 1906, Fig. 24.)

called clay seams. Such a belt may be called a shear zone or kink in the formation (Fig. 11) as though some gigantic pair of shears had started to cut the formation apart and make a fault, but had stopped in the act.

Some of the beds of the copper bearing (Keweenawan) series are copper bearing for long distances,—so-called bedded lodes. The Kearsarge lode, so-called, is being mined from the La Salle, the south line of T. 56 N., R. 33 W., to the Ojibway, Section 14, T. 57 N., R. 32 W., that is 13 miles, and it is known to bear copper in paying quantities, at least in hand specimens, for twice this distance.

Now when such bedded lodes are crossed by fractures a change in their productiveness occurs. This will be gone into more fully in a chapter on the distribution of copper. Toward the end of Keweenaw Point, where the dips of the beds are relatively flat in the upper part of the formation, the cross-fissures were the first and most extensively mined and the bedded lodes are richer near them. Near Portage Lake the reverse seems quite as often true.

§ 5. SLIDES.

Fractures running across the formation are by no means the only ones which are present. If we bend up a pack of cards we notice a good deal of slipping of one card over the other. Unquestionably there has been much slipping of one bed over another in the uptilting or bending of the Keweenawan beds. Sometimes this is shown by a polishing of the two different beds adjacent to the contact line, "slicken-sliding" it is called. The polish is not perfect and the direction of motion is indicated by scratches. Sometimes one or both of the beds lying next to such a slide are shattered with small fractures or rubbed down to a red clay called fluccan.

But probably more often than it is easy to prove these slides do not run at all times exactly with the beds but dip more steeply.[2]

All these fractures parallel to the strike of the beds are liable to be called slides as well as veins. If, however, we assume that when these faults are not parallel to the bedding they dip more steeply, such faults, if they do not produce repetition of the same

[2]A very well known illustration of the kind occurs in the Michigan mine (formerly Minesota with one *n*) in which the "North" vein which dipped 52° to 64° came down on a conglomerate which dipped about 44°, the two intersecting at the 40-fathom to 60-fathom levels, where the greatest masses of copper ever found were located, as described by Lawton in the report of the Commissioner of Mineral Statistics, 1880, p. 76. A mass weighing about 500 tons, 46 feet long, 18½ feet broad, 8½ feet thick, average breadth 12½ feet, average thickness 4 feet, was the largest.

bed, but strike out a part of the series, must be really slides, or as it is called "normal," as shown by the following figure (7).

By studying Figure 7 one can see that shafts or drill holes might miss the conglomerate entirely or seem to find the bed beneath abnormally thin owing to a downward displacement of the bulk of the strata (bed d-e). Now, as a matter of fact, in matching the records in various shafts, drill holes and cross-cuts it much more often seems as though something was gone, than as though some set of beds were repeated. For instance the well-known "slide" under the Greenstone often seems to have wiped out of existence the Allouez conglomerate. The Kearsarge conglomerate appeared at the bottom of the Central mine, but was wiped out in higher

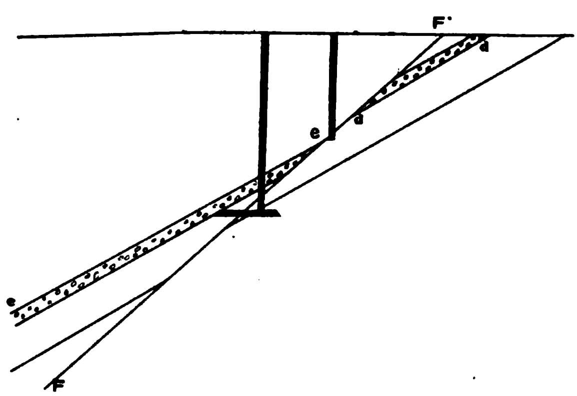


Fig. 7. Illustrating effect of normal slide faulting.

levels.[3] Another slide has in many places reduced the Wolverine sandstone to a mere remnant. It is easy to ascertain when a well-known conglomerate is gone, but not so easy to ascertain that a trap bed is merely reduced in thickness.

§ 6. CHARACTER OF THE BEDS.

The commonest copper bearing rocks are mainly old lava flows, and the usual type is much the same as any ordinary trap or basalt. The amount of silica in the trap rock is about 46 per cent, alumina 15 per cent, iron oxide 13 per cent, lime to 10 per cent, magnesia, say 7 per cent, soda 3 per cent, and not over 1 per cent or 2 per cent each of carbon dioxide, combined water, titanic oxide and potash. Other ingredients are present in only a small fraction of one per cent. The composition as a slag would then be not far from the following:

$$(CaO)\ (MgO)\ (Na_2O\ FeO)\ (FeAl)_2O_3,\ 4(SiO_2).$$

[3]See Lake Superior Mining Institute, 1895, Plate IV.

This would be nearly the composition of the mineral known as augite, but in such a rock there would be only 25 per cent to 30 per cent of augite, a little over half would be a lime soda feldspar and the balance would be magnetite or ilmenite, chrysolite (olivine) and chlorite, zeolites and other minerals usually called secondary. Such a rock, if so coarse that both feldspar and augite can be recognized, would be in Pirsson's and Chamberlain and Salisbury's field classification, a *gabbro*—if less coarse, so that while the constituent feldspar is plainly observable the dark mineral can not be made out (and good geologists have indeed often mistaken augite for hornblende in these rocks), a *dolerite*, while if finer yet it would be, if not porphyritic, a *basalt*, if porphyritic, a *melaphyre*. All these varieties *may* occur in one and the same lava flow, and it is convenient to have some term to apply to a lava flow as a whole regardless of its varying coarseness of grain. We might call these flows *traps*, but time-honored usage in Lake Superior discriminates the main massive part as *trap* from the originally porous upper part as *amygdaloid*. These are semi-popular terms.

The term *gabbro* is kept for the deeper-seated intrusions. Most of those rocks which are generally fairly uniformly coarse in grain are *gabbro*. All the effusives are wholly or partly of the melaphyre type. So we continue to use the term *melaphyre* for the dark colored lavas generally, and call the coarser streaks *doleritic melaphyre*, instead of *dolerite*.

Since many writers confine the term basalt to younger, more vitreous rocks and very many apply it to porphyritic rocks, and since this term has not been much used in connection with these Keweenawan rocks, the term melaphyre being used by Pumpelly, Irving and most writers, we shall not introduce it here, but continue to speak of melaphyre, feldspathic melaphyre, and luster mottled melaphyre, or ophite. The chemical character of these rocks is the subject of a separate chapter and has recently been quite fully discussed by A. Winchell. Variations in composition arise in these rocks from increase in silica or soda and decrease in lime when compared with the prevailing types. In either case the rock is liable to be relatively finer grained considering its thickness. As the soda increases and the lime diminishes we find a strong tendency for the feldspar to have crystallized out earlier and occur clotted together (or glomeroporphyritic) in lighter angular light greenish or reddish forms on the porcelain-like mass of the rock. Such crystals are called porphyritic crystals (phenocrysts). Large

porphyritic crystals are characteristic of certain beds, the foot of the Kearsarge lode, for instance, and the Ashbed melaphyres.

As the silica increases there is a strong tendency to flesh, red, and light colors, and the occurrence of phenocrysts of white feldspar, or of quartz either round or nearly square. If the quartz particles are inconspicuous the rock is called felsite, if conspicuous quartz porphyry, or as has been suggested quartzophyre.

These traps are mainly surface lava flows or sheets, like those that fill the Snake River Valley in the west, and cap so many mesas, and line the flasks of volcanoes like Vesuvius, Etna and Kilaüea.

The top of each flow is naturally more likely to be open in texture, full of bubbles, and thus more porous and easily crushed. Such tops are known as amygdaloids, and they are sought by the explorer, for in the filling of their pores the copper may be concentrated. A real amygdaloid top to an independent lava flow is likely to be fairly persistent and has numerous round walled cavities often filled with some white mineral. Its top is commonly pretty well marked while its base fades out gradually into the underlying not bubbly compact part of the flow which is distinguished as "trap."

But just as modern lavas or streams of slag are liable to gush over and envelope cooled crusts, or crystallize and leave cavities like those lined with melilite crystals in the pots of slag from the copper cupola furnaces, so was it with these old lavas. Amygdaloidal streaks often run down into the trap, and amygdaloid spots, bombs, or inclusions, characteristic under the Wolverine sandstone, are often found in the solid trap, and coarsely and openly crystallized "doleritic"[4] streaks are also found especially in very thick flows, and between the crystals, calcite, etc., may form giving these streaks also a spotted and amygdaloidal appearance.

The trap under the amygdaloid, the foot wall trap, is liable to be relatively lighter and more feldspathic, feldspar being the lighter mineral. The feldspar is generally oligoclase or labradorite, and appears as rice-like grains if the rock is coarse enough. The darker interstitial matter is mainly augite or its alteration product, chlorite. The olivine is easiest recognized when it is more or less changed to a reddish micaceous mineral. The magnetite is not conspicuous in the hand specimen, but is easily at-

[4]Vol. VI., Part I., Pl. 6, Fig. 3 and p. 167. I think the feldspar crystallizes better in the presence of steam, and that these doleritic streaks are where the lava had more water vapor.

tracted from the powder by a magnet. The hanging wall trap is generally darker and more augitic.

If the rock is very feldspathic and the feldspar is oligoclase there is a strong tendency for the feldspar to crystallize out early, either in sharp crystals or in groups of crystals which, where somewhat decomposed, are quite easily mistaken, especially in the uncertain light of the mine, for the white filled amygdules. Such traps are particularly conspicuous above the "Greenstone" at about the horizon of the Ashbed.

At other times as we have said large crystals of labradorite feldspar are characteristic of a flow. This is true of the big trap whose amygdaloid top is the Kearsarge amygdaloid. When the flows are very feldspathic or siliceous the grain tends to be fine, the fracture conchoidal, the ring clear. When the flows are very augitic the feldspar laths are imbedded in the augite and the olivine and magnetite are crowded between the augite patches. These augite grains increase in size from the base of the flow toward the center. The increase is not absolutely regular and depends on the composition and other circumstances as well, but very commonly the diameter is 2 to 3 ten-thousandths of the distance from the margin.[5] These rocks Pumpelly very graphically called luster mottled melaphyres, since a freshly broken piecé held in the light shows lustrous mottlings here and there from the cleavage faces of the augite, which appear as patches interrupted by the enclosed feldspar. The fracture of such rocks is rough and hackly or bubbly, not smooth and conchoidal like porcelain or glass.

On a weather beaten surface the augite centers seem more resistant than the interstices which give the pock-marked appearance that caused the rock to be called in Foster and Whitney's time, Varioloid greenstone.[6] This occurs in *various* beds, but shows up beautifully in the great ridge locally known as the "Greenstone" on Isle Royale (Plate I),[7] at Monument Rock, and elsewhere, and on the crest of the ridge that rises above the Cliff, Phœnix, Central and other old mines of Keweenaw Point. I owe to Mr. W. J. Penhallegon a number of good views. (Plate II.) This rock may finally break down to a coarse gravel, the size of the particles of which is determined by the fact that many of the fragments are single augite crystals or a good part of them.

The same structure comes out, though very faintly, in color patterns, even on rather fresh specimens, in faint shades of purplish

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[5]Two to three mm. in 10 meters or yards, or at the rate of 1 inch diameter between 250 and 400 feet from the margin.
[6]House Ex. Doc. No. 69, 31st Congress, 1st Session, 1850, p. 64.
[7]Pl. VII, of Vol. VI, Pt. 1, see also Pl. VIII.

brown and green. With a little more weathering, the same structure may be brought out in shades of yellow and brown, especially on the smooth "joint" planes by which the rock is often riven. On smooth, but not polished, surfaces such as beach pebbles or diamond drill cores, the pattern is brought out better than on polished surfaces. The structure is of course obvious in thin sections. Many of these patterns resemble the mottling of a reptile's (ophidian's) back, as shown by Plate IV, and for this reason many French writers have called this texture ophitic and rocks which exhibit it, ophites, a term which I have adopted for our luster mottled melaphyre.

In intrusives the gases do not escape and the crystallization of the feldspar is promoted and the termination thereof delayed, so that it is much coarser relative to the augite and at the same time less sharply embedded in an augite matrix. In addition to the lavas are sediments which are derived from them. On Keweenaw Point there is almost no material that may not be derived from the series itself, and much of it is, as Marvine has pointed out, extremely local. But the Keweenawan conglomerates contain many pebbles of Pre-Cambrian granites and greenstones, and the Keweenawan north of the Gogebic range also contains pebbles of the iron bearing formations to the south.

The sediments are generally red, maroon or purple and they vary from very coarse conglomerates with huge pebbles many inches in diameter to fine red mudstones. These latter often show beautiful sand ripples and mud cracks, and sometimes have curious markings suggestive of soft worm tracks (See Plate V).

The shales and fine grained rocks are rarely black. The most conspicuous case of this is the Nonesuch shale horizon which will be described later. But a few other cases occur, for instance, a bed in the Rockland district (21, Adventure section, chapter 5, § 25). Such black shales, however, seem not to be bituminous, but to owe their black color to the fact that they are made up so largely of dark particles of the trap-like serpentine. This is shown in an analysis by Dr. Gysander of the Cochrane Chemical Co., made with extra care for us. (See table of analyses, Chapter II, § 16.) It will be seen that there is practically no chance for carbon, but that the black color is due to a composition which may be accounted for by the addition of ground-up trap from which the lime has been abstracted. It is practically a black sand like those along Lake Superior. The presence of palladium, a rare and valuable mineral of the platinum group, such as are found in the Oregon black sands, is very sugges-

tive. The sample was taken from a drill core as far as possible from any known vein or lode though to be sure in the course of drilling up the Nonesuch. A corresponding variety occurs among the conglomerates, those that I am now calling *amygdaloid conglomerates* because they have many amygdaloid pebbles in them. I have also called them *scoriaceous conglomerates,* but the former name reminds one of the fact that they look a good deal like amygdaloid and at the base run into scoriaceous amygdaloid. They have been called *ashbeds.* But the real volcanic ashbeds like the Mesnard "epidote,"[8] are puzzling fine grained beds. *Clinker beds* would be a better term for these rocks. Moreover, in genuine volcanic bombs and scoria there is a variation in texture from the margin to the center. This is sometimes the case in these conglomerates but not always. We need a term to include all those beds which are characterized by a red shaly cement, matrix or base in which are pebbles of the traps. The red sandy and shaly matter also works into the loose clinkery top of the lava and makes scoriaceous amygdaloid, and it is often impossible to tell where the base of one of these amygdaloid conglomerates is, especially in drill cores. In fact this red shaly or sandy sediment may work far down into the old lava beds or traps, following the cracks that formed as it cooled, and to such little red sediment-like veins I have applied Wadsworth's name of *clasolite.*[9] Clasolites are generally red or gray or epidote yellow-green, and to all intents and purposes the same as the matrix or filling in the amygdaloid conglomerates. Such shales may also be caught up by the lava in its flow.

A conglomerate may change from a conglomerate of red felsite pebbles to an amygdaloid conglomerate in a very short distance. The Calumet and Hecla conglomerate, only a few miles south of the Franklin Junior, as Hubbard showed, and even nearer, is an amygdaloid conglomerate. One feature of all of the conglomerates, especially the smaller and lower beds is worthy of attention. Not only is the material largely derived locally from the formation itself, but it is only slightly rounded. This is notably the case in the Calumet and Hecla conglomerate itself which has accordingly been described as a *breccia,*—a term which it is convenient to reserve rather for angular aggregates made by the breaking up of the beds by disturbances.

This angular character of the pebbles is naturally to be accounted for by the fact that they seem in many cases to have been

[8]Which do occur, through Irving did not happen to strike one (U. S. Geological Survey Monog. V, p. 32). They are not thick or conspicuous so far as I know.
[9]Which may be briefly defined as clastic vein.

transported only a short distance. For instance, the quartz porphyry pebbles of Calumet seem to have come from a quartz porphyry only three miles away. Such facts would be explained naturally by supposing that the conglomerates are land formations, and in fact red colors are supposed to be often a characteristic of land formations. A deposit of red desert sand, wind blown or washed in by occasional floods, would be altogether natural on the tops of old clinkery lava flows, and it is easy to see how such amygdaloid conglomerates would form.. In many of these amygdaloid conglomerates, there is a sharp break in character between the very fine sandy matrix (which looks much like the dust and sand I collected on mesas out west), and the pebbles or scoria which on the whole can be easiest explained in some such way.

Another fact that would suggest that some of these conglomerates were formed on a land surface rather than as marine deposits is the fact that thin beds are found to be persistent above and below lava beds that vary enormously in thickness. An illustration of this is the two conglomerates (Marvine's 15 and 16), one just below the other, not far above the "Greenstone," which thickens from less than a hundred feet near Portage Lake to probably over a thousand out on Keweenaw Point. The distance between the two conglomerates, 15 and 16, each of which is supposed to be continuous, increases in the same way. The most natural explanation supposes that the two conglomerates were old land surface formations, though this is not the only explanation.

That the felsites should weather into a mass of angular fragments, a cross between a conglomerate and a breccia, is entirely in accordance with their usual habit of weathering.

The writer is therefore now inclined to consider the Keweenawan as more largely a land surface formation than he did in writing his paper on Mine Waters for the Lake Superior Mining Institute in 1908. In this his views have been modified by discussion with Huntington, Barrell and Leith, quite as much as by his own widening experience. This does not by any means imply that many of the conglomerates were not laid down in standing water and others by running water, for they certainly were, but that one must be very cautious in assuming that they were laid down in sea water, though they may have been laid down in lakes.[10]

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[10]See Fenner's discussion of the New Jersey Traps, Journ. of Geol. XV, No. 4, (1908) p. 299.

Torch Lake section given later has convinced me that the g-

[11]Annual report for 1905.

enner's discussion of the New Jersey Traps, Journ. of Geol. ...
299.

§ 7. GENERAL SUCCESSION OF KEWEENAWAN ROCKS.

(1.) *Lowest rocks. Bohemian Range Group.* When work was begun on the Black River cross- section northward from near Bessemer on the Gogebic range, the writer expected that the traps of the South Range, which extend from the south end of Lake Gogebic to this place, would prove to be a repetition of some part of the main range coming down from Keweenaw Point and lying north of the Duluth, South Shore and Atlantic R. R..[11] This cannot be made out.

The traps from Bessemer to North Bessemer appear to be older than any rocks exposed north. While there are many flows of ordinary character, there are also beds with very conspicuous porphyritic feldspar, something like those below the Kearsarge lode, but more slender. The trap itself is peculiarly blue-black and fine. Quartz and agate amygdules, sometimes of good size, are common. Elongate, so-called pipe, amygdules also occur. Intrusive diabase dikes, near the Bessemer poor farm an intrusive tongue of coarse gabbro, and near the top of the series a genuine feldspar porphyry capped by an angular conglomerate of felsitic breccia combine to give this part of the series a peculiar type. To be sure, high up in the series the Chippewa felsite and associated rocks of the Porcupine mountains have certain points of resemblance to these, but there are a number of dissimilarities such that I can not take them to be the same.

A somewhat similar series of beds also forming the base of the visible series has been carefully described by Dr. Hubbard from the Bare Hills and the mouth of the Montreal river and the south slopes of Mt. Houghton and Mt. Bohemia. The uppermost layer is what Hubbard calls the Mt. Bohemia conglomerate, and up to this horizon occur effusive and intrusive felsites. The Mt. Bohemia gabbro cuts nearly up to this horizon, and may be younger. We may call this the Bohemian Range group. North of Bessemer the thickness seems to be 9,500 feet, but there are probably not over 500 feet of sediment.

The presence of this group between Calumet and Portage Lake and farther south along the range has been an uncertain question. Hubbard made out a strong case for the identity of the Bohemia conglomerate and the so-called St. Louis conglomerate on Section 30, T. 56 N., R. 32 W., and Section 35, T. 57 N., R. 32 W., but that was as far as we have dared carry it with any assurance. The Torch Lake section given later has convinced me that the general

[11]Annual report for 1905.

horizon of the Bohemia conglomerate is that of Marvine's Conglomerate 8, exposed just back of the Arcadian and Isle Royale workings.[12]

Conglomerate 8, the top of this group, we assume, passes a few hundred feet below the Arcadian, Isle Royale and Winona lodes. which appear to be practically identical and may be the same as the first conglomerate south of the bluffs at the Lake, Mass, and Adventure bluffs (*not* the Minnesota *then*). The 2,500 feet of beds between it and the Baltic conglomerate near Portage Lake contain not less than four well-marked red conglomerates, while the traps toward the base are good heavy beds (ophites) 100, and in the case of the Mabb ophite over 200, feet thick, with clinkery amygdaloid tops, very hard to distinguish from amygdaloid conglomerates, especially if at all disturbed. Marvine in Volume I of these reports numbered the conglomerates around Portage Lake. The four conglomerates just mentioned are his 8 to 5. For further details see especially Sections 5, 14 and 16 of Chapter V.

(2.) *Central (Mine) Group.* This group is as well exposed in the Central mine as anywhere else and in the diamond drill section thence south (q. v.). The Clark, Empire, Mandan, Manitou, Central, Phoenix, Cliff, Calumet and Hecla, Torch Lake, La Salle, Franklin Junior, Arcadian, Isle Royale Consolidated, and Winona sections (q. v.) all develop this series. The various exposures in Houghton village from the College of Mines to Hurontown creek beyond the Copper Range station, show the beds. This is a new name I have introduced, naming it after the Central mine, with the thought also in mind that it really covers physically the center and backbone of the Keweenaw Ranges. I placed the lower limit at the top of the Bohemia conglomerate, and the upper limit at the St. Mary's "epidote," a small genuine volcanic ashbed which often looks jaspery and occurs just above the Greenstones.

Thus limited this group is characterized by few and thin conglomerates,[13] but numerous, and at times very thick, lava flows of uniform composition, on the whole not far from that of the standard ophite.

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[12]The arguments will be given later. Briefly, the strong group of Conglomerates 8 to 5 are not represented between a narrow felsitic band which almost surely represents the St. Louis conglomerate and Mount Houghton felsite horizon, and the dips of the Torch Lake and Douglass Houghton section are flat enough to swing these conglomerates into line. In that case the Isle Royale Consolidated section would show (721 + 1753) (2473) feet of this group at Houghton down to the Baltic conglomerate and including the Baltic lode, the base of the series not being reached. Unless there is repetition by faulting the workings of the Lake and North Lake and similar developments would also be in this group.

[13]5.65% of 8,500 feet at the Arcadian, 6.65% of 6,247 feet on Isle Royale (400 to 500 feet of sediment).

On Black River the thickness of the group is possbly 25,000 feet, at Portage Lake (90 + 2835 + 3015—27) 5913 feet, out on the Point about 7,000 feet, on Isle Royale (6115—2045) 4070 feet.

Of Marvine's numbered conglomerates, 15 to 9 occur in the Central mine group.

The Allouez or Albany and Boston conglomerate just under the Greenstone is 15, and is not far above the Medora lode.

The Houghton is often a triple amygdaloid conglomerate and is No. 14. The so-called Montreal lode is near it.

The Calumet conglomerate is the lucky 13.

The Kearsarge conglomerate is a heavy conglomerate around Calumet and appears to cover Marvine's 12, 11 and 10, but seems to split back of Houghton.

The Wolverine sandstone is generally, but not always, a deep red sandstone and is No. 9. It is only a short distance below the Kearsarge lode, separated from it by a trap bed showing large porphyritic feldspars, and a long way above the Isle Royale lode. For details of distances between these beds reference must be made to the detailed sections and correlation tables.

The culmination of volcanic activity is in this group. The thickest individual flow is probably the Greenstone which in the Manitou section is 1130 feet thick, but for a continuous succession of flows with no important sediment the three thousand foot interval between Conglomerate 9 and the bottom seems to hold the record.

The general course of this group and its conglomerates is made easier to grasp by Figure 8. This is an outline of Plate VIII.

(3.) *Ashbed Group.* This group was named from the Ashbed mine, and old mine which has not been worked since 1900, whose property covers a strip from the Lake Shore to the center of Section 23, T. 58 N., R. 31 W. The mine itself was so named presumably from an intention to exploit one of the amygdaloid conglomerates known by the miners as the Ashbed (Marvine's No. 17). It includes Conglomerates 16 to 18, and is characterized by lavas which contain more soda than the regular ophites and which are relatively feldspathic and fine grained.

The feldspars in these lavas appear white or green on a green or reddish ground, and are often clotted together (glomeroporphyric). As we go toward the Porcupine mountains a genuine red felsite appears in a thin horizon between Winona and Rockland. I think it extends uninterruptedly to beyond the Black River section, and forms the main mass of the Porcupine mountains. This region seems to have been the center of its dispersal. Intrusive

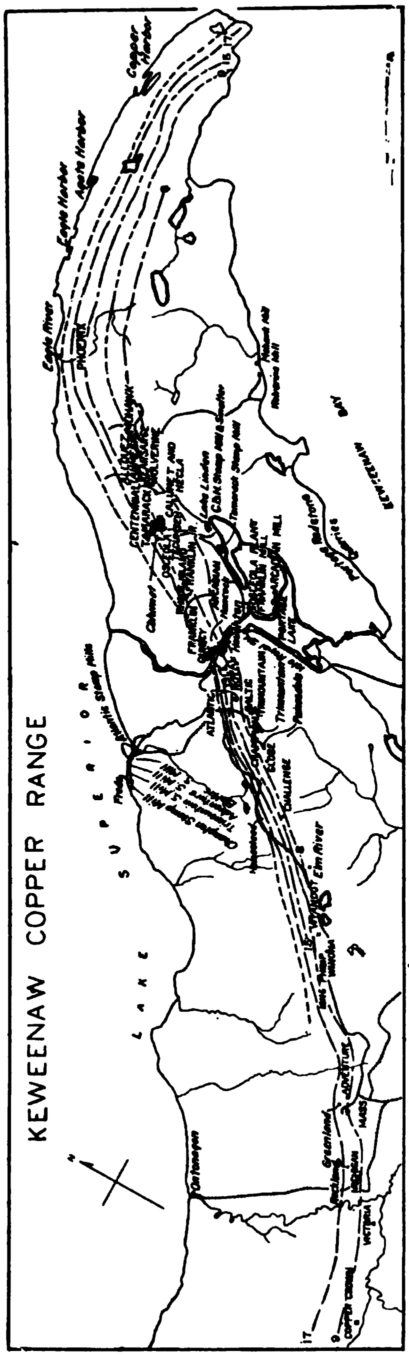

Fig. 8. Outline Map of the Keweenaw Copper Range. After Mines and Minerals, 1906, p. 205.

felsites are found in the Porcupines and between them and Lake Gogebic. The Tamarack shafts are sunk in this group. It is 2400 feet thick there, but on Isle Royale (2045—806) only 1239 feet thick.

I am tempted to regard the Mesnard epidote, which is a volcanic ash, as a correlate to this felsite. At any rate, associated with it are some conspicuous porphyritic beds of darker color, which may represent the other beds of the Ashbed group. If one considers that this horizon can be fairly well followed throughout Michigan, even across Lake Superior to Isle Royale, one is justified in expecting it elsewhere, for instance, in the Temperance River group of Minnesota.

(4.) *Eagle River Group.* This group is characterized by waning volcanic activity. It contains numerous sandstones and conglomerates, and on the whole they are more rounded in this group than in others. The individual lava flows are generally not thick nor coarse grained.

In this 2300 feet Marvine estimates 860 feet of sediment. Around Calumet 1700 feet may be assigned to it and on the Black River north of Bessemer 1417 feet.

Tamarack shaft No. 5 reaches downward to a point a little above the top of the Ashbed group, while shaft No. 2 starts at a point nearly down to the Kearsarge amydaloid giving a section from 3640 feet above the Calumet and Hecla to 1420 feet below (5060 feet), as illustrated by Figure 9. See also the cross-sections in Volume V, Part 1, and elsewhere given in this report. (Figs. 36 and 37.)

The conglomerates which occur around Copper Harbor were treated and mapped together by Douglass Houghton who considered the intervening Lake Shore Traps to be intrusive dikes. When these were found to be continuous interbedded flows the conglomerate above the traps was called the Outer conglomerate, the one below, the Great conglomerate. Hubbard showed that there is at least one conglomerate separated from the Outer by trap above it and from the Great conglomerate by trap below. This he called the Middle conglomerate. But we do not know that these traps which break up the mass of conglomerate and represent the last phase of volcanic activity in the Lake Superior region are everywhere persistent,—in fact north of Calumet they almost disappear and they have not been found in the vicinity of Houghton. So there seems to be a real need for a name for the group as a whole and after consultation with a number of fellow workers "Copper

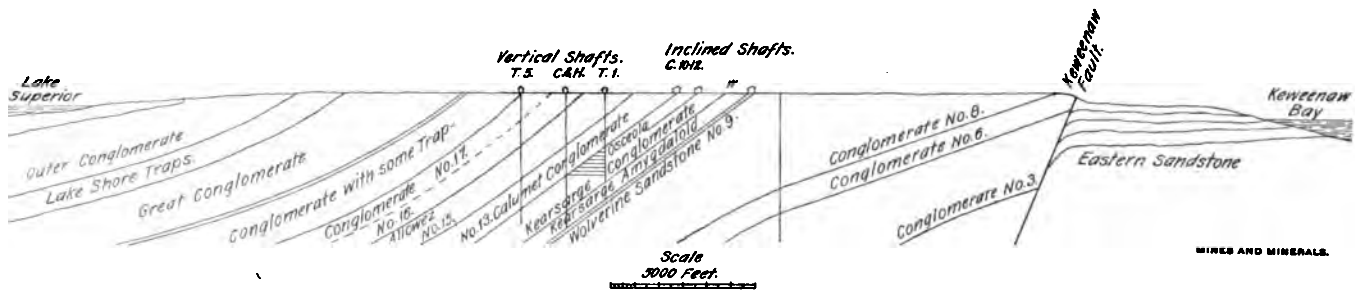

Fig. 9. Outline cross section near Calumet. After diagram prepared for Mines and Minerals, 1906, p. 204.

Harbor conglomerates" seems to be best. When they are separated by the Lake Shore traps into two or three parts one can still apply the adjectives Great, Middle and Outer, and indeed need not always give them the full title. For "Great Copper Harbor conglomerate" or "Middle Copper Harbor conglomerate," one may still say "Great conglomerate" or "Middle conglomerate" when the meaning is clear.

The disadvantage in thus grouping the conglomerates is that Irving made the line between Upper and Lower Keweenaw at the highest and youngest known[14] igneous rocks, the top of the Lake Shore Traps. Thus the Outer Copper Harbor conglomerate is the base of the Upper Keweenawan.

(5.) *The Great Copper Harbor Conglomerate* is a coarse heavy conglomerate at base, with large generally well rounded pebbles of great variety, mainly Keweenawan. Its thickness, not allowing for initial dips, varies from 1800 to 2200 feet at Eagle River and Calumet to possibly 340 feet (?) on Black river, but apparently it is much thicker in the Porcupines.

The top of this group under the Lake Shore trap in the Porcupine mountains is a hardened red mud which is highly charged with epidote and calcite and occasionally with copper. Throughout the formation there are, above the base, alternating streaks of more or less coarse red sandstone and mud rock (red shale) and true conglomerate. Conglomerate is generally the most conspicuous.

(6.) *The Lake Shore traps* are a series of flows, none very thick, the total thickness varying from 1800 feet at the end of Keweenaw Point to 900 feet at Calumet and 400 feet on Black river. They are apparently absent around Portage Lake.[15] They represent the last volcanic outbreak in the Lake Superior region. The Lake Shore traps are melaphyres without any very distinguishing trait. The amygdules are generally rather coarse.

(7.) *In the Outer Copper harbor conglomerate* on Black river may be found pebbles representing all the Lower Keweenawan types including intrusives, amygdules and agates, and also Huronian iron bearing jaspilites and other rocks. A thickness of only 1000 feet is given for the Outer conglomerate on Keweenaw Point. Gordon makes the thickness 5000 feet on Black river, Irving 3000 feet in the Porcupines.

The upper quarter is largely sandstone, the lower quarter largely conglomerate. The Nonesuch lode is *really* in this formation just

[14]The one occurrence, reported by Irving, of a dike cutting the Upper Keweenawan near Lone Rock north of the Porcupines, proves not to be such.
[15]See Chapter V for discussion of relation to Middle conglomerate.

under the Nonesuch shale, being a rather striking conglomerate, the general body a coarse greenish sandstone or fine conglomerate in which are bright brick red pieces of red rock (gabbro aplite). The analysis of the Point Houghton sandstone would probably fairly represent its composition.

The presence in these Copper Harbor Conglomerates of numerous pebbles which, if correctly identified, are of rocks intruded into the Keweenawan at some depth, and of agates, etc., formed in them tends to show that the earlier part of the series must have been considerably eroded, being either uplifted or forming from the very first a land formation exposed to erosion. As erosion continued the knobs of felsite, the harder quartzose red rocks, seem to have been worn down the material becoming finer with more of the dark basic lavas in the sediment.

(8.) *Nonesuch Shales.* The Nonesuch shales are quite uniform and persistent in thickness, appearance and distribution. Their thickness is 350-400 feet on the Montreal, 500 feet at Black river, 600 feet in the Porcupines, and somewhat the same near Rockland. Thence north their occurrence is not so well known, but they appear to pass Portage Lake on the powder company's lands, Section 28, T. 55 N., R. 34 W.

The shales are black, fine grained, micaceous, sometimes greenish, and grade into greenish flags or grits and sandstones. Some of the sandstones have bands of iron ores which completely cover the cleavage faces. The black color is, therefore, due to iron and chlorite and not to organic matter as the analysis proves. It has no more iron than the red sandstones, but the iron is combined with alumina, magnesia and silica, into green minerals like those which occur in the altered conglomerates and amygdaloids. The Nonesuch must have been formed under such conditions that the iron oxides did not readily rust and oxidize. It preserves, beautifully, ripple marks and mud cracks, and seems also to contain traces of crawling animals or sea weed. (Pl. V.)

(9.) *Freda Sandstones.* Above the darker shales and grits of the Nonesuch, red beds appear again,—generally a red, impure sandstone, sometimes conglomeratic and sometimes red shale, in general much like the Outer and Great conglomerate, except that the conglomerate becomes less and less abundant. The higher beds were well exposed near the new stamp mills at Freda and all along the adjacent shore. A drilled well at Freda showed a thickness of not less than 900 feet. They can not be less than 1000 feet thick there though the dip is much flatter than the beds

above, more like 10 degrees to 30 degrees from 4000 feet to 12,000. Irving estimated 12,000 feet of thickness in the Montreal section. I strongly suspect a repetition by faulting there, but even if this is so there can be hardly less than 4000 feet.

The relation of these sandstones to the Jacobsville sandstone, and the Apostle Islands sandstones, which all agree to be Cambrian, is a moot point. I believe that the Freda sandstone correlates with the beds of Clinton Point, which Irving grouped with the Cambrian. A full discussion of the grounds for and against the Cambrian age of the Keweenawan must needs be technical, but the writer is inclined to class the Keweenawan as Cambrian, and this much at least of the argument anyone can appreciate, that between the formation of the Freda sandstones and that of the Upper Cambrian sandstones, which are similar to them, nothing is positively known to have happened,—no igneous activity for instance.*

§ 8. SOURCE OF THE COPPER.

Much thought has been spent upon the question of the source and distribution of the copper. After Pumpelly's masterly work on the copper bearing lodes,[16] and the summaries given by Irving and Wadsworth especially, little needed to be added for years. Additional facts have been accumulated, however, and with the growing importance of the western deposits, there has appeared a tendency to apply the same principles that have been used in explaining them to these and other similar deposits of native copper and ascribe the copper to solutions rising through fissures from beneath, charging the formation with its precious content. This view has been especially represented by Smyth and Van Hise. Those connected with the Michigan Survey have never accepted this view but have believed that the copper belonged to the Keweenawan formation itself, and had been segregated therein by wandering waters, which have been generally thought of as working downward.

This whole report is an assemblage of facts bearing on this problem. A few points may be grouped here.

1. The dissemination of copper in small quantities throughout the formation. The average from several thousand feet of drilling at the Clark-Montreal was 0.02 per cent. Hardly a single amygdaloid fails to carry less than .02 per cent copper, and when the copper content reaches .50 per cent it is nearly an ore.

*See also U. S. Geol. Survey Monograph 52, pp. 413-419, and p. 379. In this Monograph doubt is thrown on the Cambrian age of the Apostle Islands sandstones, but my view as to their relation to the Freda is accepted.

[16]Volume I of these reports; Volume III of the Wisconsin reports.

2. The occurrence of native copper in similar formations of red rock associated with salt waters and lavas elsewhere,—notably the New Jersey Triassic, in the Bolivian Puca sandstone, in Nova Scotia, around Oberstein in the Nahe melaphyre region, and in Alaska.

3. The general absence of native copper outside the Keweenawan, in the Lake Superior region, but—

4. Native copper has been found in iron ores (generally thought to be formed by the action of downward working waters) in a few places.[17]

5. The water in the formation is of three kinds:

a. At and near the surface, soft and fresh with sodium in quantities more than sufficient to combine with the chlorine.

b. At some distance (generally 500 to 2,000 feet, before it attracts attention, unless especially sought), the chlorine is higher and the water is charged with common salt. The line between the two classes of waters is often quite sharp.

c. At great depths a strong solution of calcium chloride containing some copper.

6. The middle water (b) often contains more salt than it could possibly have were it a mixture of a and c.

7. The lines between the different kinds of waters are not regular, yet the lowest water probably always comes within two or three thousand feet.

8. The amygdaloids seem, other things being equal, to contain rather stronger (more saline) water than the conglomerates.

9. An unequally heated solution corresponding in composition to mine water (c) will precipitate copper on the same minerals, prehnite, datolite, etc., on which it occurs in the mines, as Fernekes has shown.

10. The traps contain combustible gases, as R. T. Chamberlin has shown.

11. Certain beds are abnormally high in copper for many miles.

12. Copper often replaces chlorite, and in the Calumet and Hecla pebbles chlorite replaces felsite, and the copper the chlorite.

13. Copper may even replace vein quartz.

14. Copper is formed generally after those minerals which are the products of alteration and contain lime, and before those secondary minerals which are the products of alteration and contain soda and potash.

15. Therefore at the time the copper formed the mine water

[17]Report for 1903, p. 247.

might have lost lime but could not have lost sodium. The rock might have lost both.

16. The Calumet and Hecla lode averages less rich (very rich in spots) near the surface, attains its greatest richness at a certain depth, say about 2,000 feet, and then gradually decreases in richness.

17. The silver occurs more abundantly in the upper levels.

The conclusion to which these facts have forced me is that the copper was in the Keweenawan formation as a whole, before being introduced into the particular places where we find it, and that the deposits have gathered together[18] by migration of the particles known as ions in the chloride solution, just as in the formation of electrolytic copper in an electrolytic bath the copper goes toward the electro negative pole and the more electro positive or alkaline parts of the solution, and as in Fernekes' experiments, toward the hotter parts of the solution. That the copper should actually be precipitated as a metal, however, depends upon a delicate adjustment of the composition of the solution in which the affinities of iron for oxygen may play an important part. For the copper to be precipitated the solution had to be kept neutral or alkaline and reducing in the part where the precipitation took place. And in the accumulation of copper into workable deposits not merely the electrolytic migration of the copper in the solution but the currents and circulation of the solution of the water in the rock have to be considered. In producing this solution and guiding its circulation, the following factors have to be considered:

(1.) The water originally contained in the lava.

(2.) That which early filled it whether it was buried on land or beneath seas, which may have included condensed volcanic vapors containing copper chloride as in Stromboli, or in the evaporation of desert pools.

(3.) The absorption of water in the hydration of the rocks.

(4.) The absorption of water in the cooling of the formation (water in cooling shrinks more than rock).

(5.) Faults in the formation facilitating the intermingling of solutions of different compositions.

(6.) Erosion of the formation and concentration of the copper contained either in pools on the land surface or in the water which found its way down into the rocks, while the deposition of the Keweenawan as a land formation was going on.

(7.) The ordinary circulation of the water entering at the higher parts and emerging in springs.

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[18]Been segregated.

Now, all of these may have had some influence. Most of them *must* have had some. It may well be that the next great discovery of copper will be one of a new type in which some factor so far apparently unimportant becomes the dominant one.

As to the importance of these various factors, however, a few words may be said, though reference must be made to the detailed work. Absorption of water seems to me of first importance in the accumulation of copper, round and round circulation of less. To suppose that the wide spread calcium chloride waters are always volcanic is to suppose that the earth is everywhere sweating,—a sweat salty with calcium chloride. But to this theory there are serious objections. It must remain unsafe then to say to just what extent various sources participated in formation of the mine waters. We may, however, look back to a time when the formation was filled with a water whose main acid was chlorine, but the base was not sodium. This is the practically important thing. Whether oceanic in origin or not these chloride waters are as universal as the oceanic when sufficient depth is attained, and though they vary in strength for the same depth, I have not yet been able to find signs that, other things being equal, there is more chlorine near certain fissures or in certain districts. The reverse of this, that there is sometimes less chlorine near fissures where the circulation has obviously been free, is true. This may be used as an argument against the introduction of the chlorine from without.*

In the accumulation of copper, and after soda may have replaced lime in the mine water, an early occurrence of salt water of the calcium chloride type does not appear especially favorable. In the upper levels, however, where the water is fresh and there has been a good deal of circulation, the copper may be all washed out.

The distribution of the copper in a lode may perhaps be likened to that of the matter on a slime table, bare at the center or top, heavy in spots and streaks in the middle, more uniformly but thinly scattered toward the lower and outward margin.

One thing is noteworthy in a number of cases—a tendency for the copper to accumulate under heavy impervious beds, extending perhaps in thin sheets up into the joints of the same,[19] but even

*These waters are discussed in the Lake Superior Monograph 52 on p. 544. "In deep underground waters there is essentially the same condition of stagnancy, and therefore we suggest progressive accumulation of soluble chlorine salts." But in spite of the stagnancy Van Hise and Leith see "no adequate reason for regarding these waters as fossil sea waters."

[19]Copper under the Lake Shore traps, under Nonesuch shales, under Greenstone, under Mabb ophite, etc.

more in stringers into the foot as described by Wadsworth. In such cases the heavy bed has evidently guided the circulation.

§ 9. GASES.

Combustible gas has been found in mine waters, notably at Silver Islet, but also at the Calumet and Hecla. It was natural to attribute it to decaying timbers but that explanation seems no longer necessary since R. T. Chamberlin has found that most igneous rocks yield about 1 or 2 times their volume of combustible gas.[20] Such gas or the hydrocarbons or carbides, nitrides, and silico-chlorides (found by Brun to be normal constituents of lavas) from which they might be derived[21] are powerful reducing agents that might throw out the copper.

Thus Pumpelly's explanation that ferrous salts precipitated the copper though both possible and plausible, is not absolutely necessary. It may be original carbon which produced the calcite which is the mineral most intimately associated with copper. One may readily find crystals of Iceland spar ($CaCO_3$) intergrown with native copper whose virgin luster is thus beautifully preserved. Sometimes the crystal form of calcite (the "dog-tooth"—or other shape) is plated with copper and the growth of calcite continued. Now carbon dioxide is absent from the lower mine waters, though calcite is present in the rocks and a certain amount of carbon-dioxide gas may be abstracted from them. It is easy then to suppose that a slow oxidation of hydrocarbons and carbides originally in the beds has furnished the carbonate, which formed slowly since it is in large crystals, and reduced the copper. We are then not compelled to look to the waters beneath the earth for the source of the copper.

§ 10. ALTERATIONS AND MINERALS PRODUCED THEREBY.

Pile up a series of heavy massive beds (traps) and open porous spongy ones (amygdaloids) like a layer cake, and then tilt the pile and there can be but one result,—a slump and sliding of the upper beds and a crushing of the open porous beds as shown in Figure 10, until by a process of shattering, "brecciation" and filling up and cementation of the porous beds with new minerals, they are made of nearly the same specific gravity as the rest and strong enough to stand the pressure. This is what has happened to the amygdaloids. Even the most casual visitor will be able to see in the

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[20] Including a sample from a deep core sent by us; "The Gases in Rocks," published by R. T. Chamberlin, pp. 20-24, 33, 34.

[21] Another possible react.on suggested in Chamberlin is: $6 FeCl_2 + 3H_2O = 2 Fe_2Cl + Fe_2O_3 + 3H_2$.

mine dumps and at the stamp mills the soft white cleavable calcite, the white or colorless glassy hard quartz, the yellowish green epidote, and the darker bluer greens of the chlorite (delessite) group, and serpentine. Prehnite, white with a faint greenish tinge, is a common associate of copper. Laumontite, reddish and readily crumbling, is not so favorable a sign of copper. Datolite, almost like porcelain, often with beautiful flesh, and other tinges, is one of the last minerals formed. Datolite is polished to form articles of jewelry as are also chlorastrolite, thomsonite and agate. The concentric banding of the agates, which generally are large amygdules, is cut across in making jewelry, while the chlorastrolite and thomsonite amygdules are polished round.

In general, laumontite, epidote, quartz and prehnite tend to

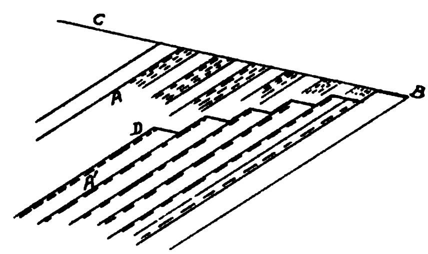

Fig. 10. Illustrates the effect of slump in a series of traps and amygdaloids, the amygdaloids being originally vesicular porous beds as thick as the traps but crushed to a fraction of their original thickness, in which process the line CB takes the position BD and the bed A sinks to A'.

antedate the copper, calcite and analcite are about coeval, while datolite and orthoclase are often later, but there is a good deal of overlapping. Sulphates like barite and selenite are rare and late comers and like the analcite and silver seem rather confined to the upper levels. I am inclined to think too, that the interesting sulphides and arsenides, the lead colored chalcocite, the tin-white chloanthite, the pale reddish nickeliferous Mohawkite, and Keweenawite, are also relatively superficial.

One of the striking factors in the development of stamp mill practice in the past 20 years is the introduction of the diagonal sorting tables of the Wilfley, Overstrom and Deister pattern, and a noticeable and beautiful feature in some of the mills is the production of bands of different colored minerals arranged on these tables according to specific gravity. Next to the copper red there may be a lead colored band of chalcocite present. The yellow-green band of epidote may next appear before we come to the

dull maroon iron rust colors of the red clays and ground up amygdaloid.

The amygdaloids sometimes have the original texture and round bubbles well preserved. Then again they are all brecciated, that is, broken up, the cementing material being calcite and epidote. Sometimes epidote and quartz replace the whole rock almost solidly. Again there is much chlorite. Where great sliding (actual motion) has taken place the rock is reduced to a greasy red clay called fluccan which the miners used to wrap in a ball around their candles for candlesticks. It is much more greasy feeling than the red sand or dust that blew into or washed into cracks in the lava and made what we call clasolites.

§ 11. SHEAR ZONES AND SHOOTS.

If we bend a pile of paper and one part of the pile more than the other, we shall find between the parts thus bent a belt where

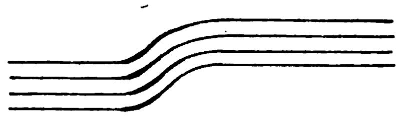

Fig. 11. Illustrates gaping beds, or pile of cards when unequally bent.

the paper tends to gape apart (Fig. 11.) So in the uneven tilting and slumping of the formation we find changes of dip and strike and at times belts of traps which have been much fissured and shattered, in which secondary action and at times copper formation has gone on, by no means confined to any one amygdaloid, though normally, movement and readjustment would naturally follow the weaker beds, the sandstones and amygdaloids. But if there is a diagonal stress, neither at right angles nor parallel to these beds, the resultant disturbance will follow the weaker beds for some distance, then jump across through a heavier trap bed, shattering it on the way, when the diagonal component of the stress, not satisfied by yielding along the beds, becomes too great. Thus a shear zone will be produced (Fig. 11), which would in many cases have a tendency to gap open and leave places to be filled by breccia and new deposits.

It is certain that some of the stresses to which the Keweenawan rocks have been subjected, have had a diagonal direction. We have noted a tendency of beds to be thrown to the right on the northeast which corresponds to the general eastward curve of the Point. As illustrated, the Quincy mine is not confined to one

amygdaloid, and the Baltic lode appears to be in a shear zone,—the Lake perhaps also.

The Calumet and Hecla shoot is shown on Plate IX.

§ 12. SURFACE GEOLOGY AND DISTRIBUTION OF FLOAT COPPER.

After the close of the main up-tilting the copper range uplift may have continued in a lesser way since beds of the age of the Niagara Limestone are disturbed at Limestone mountain. There was later some depression, since about the time the hardwoods first became abundant a sandstone was formed in the Mesabi range[22] and the ocean may possibly have reached Michigan too, though no trace of such sediments have yet been found. Probably before this time the surface was reduced to a comparative level, such as the plateau from the the Quincy to the Calumet, and some time since the Cambrian sandstones mantled the range (possibly when emerging from the Cretaceous sea), rivers seem to have established their course across the range, marking out valleys such as those now occupied by the Ontonagon river, Fire Steel, Flint Steel, and Portage Lake. These valleys may have been cut deeply in the era of elevation preceding the recent ice age, which is marked by the formation of caves such as the Osborn cave at Fiborn and by the deep valleys in the rock surfaces, now filled with drift, whose soles are at times below sea level. At the same time the minor tributaries in their erosion brought out the rock structure, generally leaving the harder traps in ridges. When the ice age came on, the earlier center of collection and distribution seems to have been northwest of Lake Superior. It is called the Keewatin center. Later the ice moved from the east, from a center in Labrador called the Laurentian center, and reaching Lake Superior moved out from it. (Fig. 49.) Around Portage Lake the ice actually moved to 10 degrees north of west. This direction of ice motion is beautifully marked near the Calumet, Arcadian, Quincy, and Isle Royale mines. One can see the stoss and lee sides of the motion, the grooves and trails left by harder knobs. The ice front, which was naturally perpetually oscillating, and the direction of ice motion and transportation, streaming away from the center of distribution and finishing at right angles to the front, also shifted. Hence copper may be found either side of its parent ledge, but that at the surface which is most likely to be found was probably left by the last ice motion. Around Calumet and Portage Lake the ice moved from the direction of Keweenaw Bay,

[22]Leith on the Mesabi Range, U. S. G. S., Monograph 43, p. 189.

and farmers plowing their fields near Portage canal reap a harvest of copper nuggets which may have come from the Franklin and Quincy.

From somewhere about the Winona mine on the south, however, the motion was from the other side. Where the motion was from the east and southeast over the eastern sandstones the surface overburden, or drift, is more sandy. The material which was ground off the range itself by the ice is a much stiffer red clay with stones in it. Great quantities of material were washed out of the ice front by water from the melting ice and deposited in sheets known as sand and gravel plains, irregular mixed masses and high hills known as kames, and long narrow hogbacks, known as eskers. Along lines where the ice front lingered some time the deposits are extra heavy and are called moraines.

Keweenaw Point and the Porcupine mountains were relatively early laid bare and made cusps or reentrant angles in the ice front. At one stage of retreat Centennial heights, north of Calumet formed a reentrant (Plate IX). Another hill of sand, Wheal Kate (1508 feet A. T.), towers south of the Mill Mine Junction and the village of South Range, and is easily recognized from the hills either side of Portage Lake. It is part of a heavy moraine which extends entirely around Keweenaw Bay and for miles south the drift is extra thick. Working through this coating which is often of light quicksand, makes explorations and mining difficult, and will retard mining development.

In front of the ice sheet the water was ponded and drained to the Mississippi. On the north side of the Porcupines the highest level of this water was 559 feet above Lake Superior. On the south side of the Porcupines it was higher, at least 34 feet above Lake Gogebic, or 720 above Lake Superior, or 1320 above tide. But around the Ontonagon Valley the beaches and benches at 565 feet above Lake Superior are much more strongly marked. The corresponding level rises as one goes out on the point, being at North Tamarack at least 640 feet above Lake Superior. Thence downward are beaches at numerous different levels formed at successively lower stages of the water. Down to 480 feet above Lake Superior (a strong beach, well-marked, where the electric road crosses it in climbing a hill near the Quincy mine), the beaches are referred to a Lake Duluth. Thence down to a little less than 100 feet above Lake Superior, the level of the strong terrace on which the College of Mines stands, the beaches are said to be of a Lake

Algonquin,[23] which covered all the upper lakes. It was drained at different periods by various outlets, a part of the time by the newly reopened Chicago outlet.

Strong beaches below the Algonquin, 30 to 60 feet above the lake,[24] are referred to a Lake Nipissing which had an outlet down the Ottawa. Possibly the bluffs and terrace on which the Freda stamp mills were placed were formed at this time. The Ottawa outlet has been raised by tilting of the land and there is reason to believe that this is still going on so that the Michigan shore is sinking as well as being cut back by Lake Superior. This is very evident along the lake shore in the Porcupine mountain region.

[23]Leverett, Twelfth report Michigan Academy of Science, 1910, Fig. 7. Fig. 2 shows Lake Duluth..

[24]Leverett, loc. cit. Fig. 8.

CHAPTER II.

NOMENCLATURE AND CHEMICAL RELATIONS OF THE KEWEENAWAN ROCKS.

§ 1. HISTORICAL REVIEW OF NAMES APPLIED TO IGNEOUS ROCKS OF THE KEWEENAW SERIES.

I wish to express especially my obligation to a paper by A. N. Winchell, published by permission of the Director of the U. S. Geological Survey[1] which I understood would represent the usage of the U. S. Geological Survey in their Lake Superior Monograph. Wherever I differ it will generally be found to continue the previous usage of the State Survey, and in this (my final report probably) it seems well not to change without the best reasons. Winchell has in view especially microscopic petrography, and his study of usage goes back therefore only to the microscopic studies of Streng (1877). Since I have in mind more the convenience of mining engineers and geologists in the field; I will go back a little farther, to give more completely the use of the terms.

Douglass Houghton in 1841 used the terms *Trapp* and *range,* and distinguished the *amygdaloid* from the compact *trap* or *greenstone,* which he defined as the compact granular variety made up of feldspar and hornblende, though he expressly stated[2] that under this term, augitic and other rocks were included. As a matter of fact, hornblende is rare in the Keweenawan rocks, and the mineral associated with the feldspar in the greenstone is generally chlorite and augite.

W. A. Burt and B. Hubbard used Houghton's terms, but since in working for the U. S. Linear Survey, under the contract with Douglass Houghton, they had come upon the Mt. Houghton and Porcupine Mountain felsite and quartz porphyries they called them *red trap* and *trap porphyry.* In the Jackson report[3] in which the

[1]Review of Nomenclature of Keweenawan Igneous Rocks, A. N. Winchell, Journal of Geology (Vol. XVI) 1908, No. 8, p. 765. See also U. S. G. S. Monograph 52, pp. 395-407.

[2]"Memoir of Douglass Houghton, first State Geologist of Michigan" by Alvah Bradish, 1889, p. 177.

[3]Report on the Geological and Mineralogical Survey of the Mineral Lands of the U. S. in the State of Michigan. Senate Docs., 1st sess. 31st Congress, 1849-50, No. 5, Pt. III, pp. 371-935.

work of Burt, Hubbard, Jackson, and Foster and Whitney and others is mingled, the main felsitic rock of the Porcupine mountain is called *jasper* and the more coarsely porphyritic rocks southeast around Bergland *quartzose porphyry.* Foster and Whitney continue to refer to the *Trap range.* The greenstone was still considered to contain hornblende. Where columnar jointed and very fine grained it was called *basalt;* when it contained distinctly disseminated feldspar crystals *porphyry* (*porphyrite* as I should call it), and the crystalline and feldspathic varieties (Mt. Bohemia gabbro and gabbro ophite) are called *sienite.* They also mention *compact trap* (ashbed or porphyrite?), *trap breccia* (amygdaloid conglomerate?), *porphyritic trap* (like the Kearsarge foot?) and *epidote trap.* In regard to the use of the term *jasper,* the *compact quartz* or *jasper* is understood to pass into the quartz porphyry.

In Volume II they discuss the terms *trap* and *greenstone*—stating that most of the igneous rocks embraced in the term *greenstone* are labradorite or oligoclase and pyroxene with chlorite and thus the term *diabase* is applied to them by continental geologists. Melaphyre they mention for the first time as "a fine grained compound of labradorite and ilmenite and (probably) pyroxene. Basalt is divided into

dolerite, crystalline aggregate of labradorite augite and ilmenite,
anamesite, a fine grained mixture of the same.

They recognized the presence of augite, though it was still put after the hornblende in importance and analyzed the Greenstone (note the capital G) from the summit of the cliff at the Cliff mine as given below.

In 1850, Fr. C. L. Koch,[4] one of the founders of Saginaw, an educated German mining engineer, visited the district and recognized (p. 201) the dark mineral as augite, and determined the trap to contain augite and labradorite with some magnetite at times and believe it to be properly called *trap* or, if the magnetite was conspicuous, *dolerite* and the finer forms as *anametite.* No progress was made on Koch for fifteen years. Rivot, professor in the Ecole des Mines, at Paris,[5] used the same terms, *trap, amygdaloid, greenstone,* and was rather inclined to believe the traps to be metamorphic sediments. A. Winchell, 1860-61, did no detailed work on the *Trappose rocks.* Thus the nomenclature of the first generation of geologists and miners still in use, to which I cling so far as

[4]Studien des Gött. Vereins Bergm. Freundé by Fr. C. L. Koch, Vol. VI. Parts 1 and 2 (1852).
[5]"Voyage au Lac Supérieur," by M. L.-E. Rivot, 1885 Annales des Mines Vol. VII, p. 173 et seq.

possible, may be said to be practically that of Douglass Houghton, Bela Hubbard and Foster and Whitney. Koch's work, published in German, was and is yet largely unknown.

The next work in considerable detail on the Keweenawan rocks was that of Thomas MacFarlane (who had just passed away) for the Canadian Survey in 1855.[6] He argued for the term *melaphyre* and also used *trap*. He speaks of the upper part of the melaphyre as being amygdaloid. He made numerous analyses. Some might object that his partial analyses were not accurate and that he overestimated the amount of chlorite. From the modern point of view his analyses are certainly incomplete, but they still have distinct value as showing what parts of the rock were attacked by acids, and have not been replaced. Even supposing that he overestimated the chlorite, the rocks which he calls *melaphyre* are exactly similar to those which around Oberstein and the region of the Nahe river in Germany have been called *melaphyre*.

Moreover, the use of the term melaphyre was continued. H. Credner, the eminent German geologist,[7] applied it to the rocks associated with the Calumet and Hecla conglomerate.

Pumpelly, with whom Credner worked, and Marvine,[8] adopted this term *melaphyre* (melaphyr) while they recognized that the chlorite is produced from hornblende or pyroxene. They distinguished the following varieties of melaphyre—an amygdaloid upper part, a central coarse grained part; fine grained with rubellan (altered olivine); and melaphyre porphyry. Marvine called the Greenstone with the big "G" *diorite*, appreciating its coarseness, but also confusing augite with hornblende? A. A. Julien,[9] described rocks from the iron country, and incidentally some Keweenawan dikes as Black *Dioryte aphanite* (355, 356). These same Keweenawan dikes, C. A. Wichmann[10] called *diabase* recognizing them as labradorite-augite rocks, but refusing to call them *dolerite* as Koch did, since he would limit that term to Tertiary rocks. He recognized the quartz diabase. His was the first application of the microscope to the examination of the rocks. Pumpelly in 1878 and 1880[11] continuing his work under the Wisconsin Survey, followed Rosenbusch's system and described many of the Eagle

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[6] "Exploration géologique du Canada, Report des Operations de 1863 à 1866," Appendice relatif aux Roches et Gites Cuprifères du Lac du Portage, Michigan, par Thos. Macfarlane, pp. 153-169. Translated in Vol. I Geological Survey of Michigan, Pt. II, pp. 9-12.

[7] Neues Jahrbuch für Min., 1869, p. 3.

[8] Geology of Michigan Vol. I, Pt. II, Copper Bearing Rocks, pp. 12-13.

[9] Microscopic Examination of Eleven Rocks from Ashland Co., Wis., Geology of Wisconsin Vol. III, pp. 224-238.

[10] Geology of Wisconsin Vol. III, pp. 621-627.

[11] Geology of Wisconsin Vol. III, Pt. II, pp. 27-40. Lithology of the Keweenawan System.

river rocks, and suggested that the term melaphyre should be replaced by the term diabase, classing the rocks as follows:

I. Granular plagioclase-augite rocks: with olivine (chrysolitic) diabase.

II. Porphyritic plagioclase-augite, with more or less unindividualized base: porphyritic diabase or, with olivine, melaphyre.

III. Granular plagioclase-diallage rocks,—gabbro.

He noted that of one great flow that I call *ophite,*— the *Greenstone*—some specimens are diabase, some (as Bed 108) near the base, melaphyre, others as (Beds 95 and 107) of the Eagle river section, gabbro.

The luster mottled rocks he described as *melaphyres,* but did not recognize the altered olivine in the Ashbed type of trap. This is not to be wondered at, for it is rarely fresh and practically *never* in superficial specimens, which were all he had. Pumpelly also made a distinction between *amygdaloid* and *pseudo-amygdaloid,* the latter being a variety of a rock resembling the amygdaloid in its speckled appearance, but the result is one of alteration, not of filling of original bubble cavities.

Irving also contributed to Volume III and found in addition to *melaphyre* and *diabase, quartz* and *granitic porphyry* and *felsitic porphyry,* which he was inclined to suspect were fragmental (brecciated felsites). The *gabbro* of the Wisconsin Survey included a gabbro proper, olivine gabbro, uralitic gabbro and orthoclase bearing gabbro, the diabase, an ordinary prevalent fine grained type with one or two coarse grained varieties, the Ashbed diabase type, a pseudamygdaloidal and true amygdaloidal phase.

Mosler in 1877[12] followed the usage of Pumpelly. In his Monograph V of the U. S. Survey,[13] Irving still following Rosenbusch's usage, makes the following classes (p. 37):

Coarse,—gabbro and diabase, olivine gabbro and olivine diabase, all free from orthoclase; orthoclase gabbro, hornblende gabbro, anorthite.

Fine,—diabase of the ordinary type, olivinitic diabase and melaphyre, Ashbed diabase and diabase porphyrite amygdaloids.

The noteworthy difference shown in the work of the decade 1877-1887 as compared with the work from 1866-1877 is the more frequent application of the term *diabase* instead of *melaphyre.* Rominger, in Volume V of the Michigan reports, written in 1884,

[12]Der Kupper Bergbau am Obern See in Nord Amerika von Chr. Mosler, Berlin, 1877.
[13]"The Copper bearing Rocks of Lake Superior" by Roland Duer Irving, U. S. G. S. Monograph V.

though not published until 1895, drops the term *melaphyre* and speaks of *diabase* and *amygdaloid, quartz porphyry,* and *felsite.* Irving (loc. cit. p. 69) called nothing *melaphyre* unless there was residuary base (glass, calling them olivine gabbro, if coarse; *olivinitic diabase,* if fine.

Many rocks among the Ashbed diabases, that I would call olivinitic he does not so count, taking the altered porphyritic olivine to be altered augite perhaps. Herrick, Tight and Jones[14] followed Irving in referring to *diabases, diabase porphyrites* and *felsite porphyry.* Wadsworth in 1779[15] classified the basaltic rocks as follows:

	Feldspar		Melaphyre	Tufa
		Basalt		"
Basalt	Leucite		Diabase	
		Dolerite	Gabbro	Poroda
	Nephelite		Peridotite	

In 1880 he gave a characteristically thorough review of the literature of the Copper districts. He uses the term *melaphyre* very frequently as a variety of basalt, uses the term *rhyolite* for the more siliceous, *trachyte* for the less siliceous felsites. He uses the term *melaphyre* almost as Macfarlane and Marvine did. Its derivation and application is the same, though he defines it as an altered basalt, and uses it[16] somewhat under protest.

In 1887[17] he examined for the Minnesota Survey among others, many Keweenawan rocks. He mentions the term *ophite* as a variety of his basalts, which take the forms of gabbro, diabase, melaphyre or diorite, according to alteration. Characteristic of Wadsworth is the emphasis he laid upon secondary changes and the account which he took of them in his nomenclature. Many things, for instance micropegmatite, that I should consider primary, he (and Irving followed him), considered secondary. Yet I found as I worked with him for two or three years that we would agree in a great many cases in the application of names though disagree in our conclusions and definitions.

Yet I agree that melaphyre *may* be essentially altered basalt. His last formal work for the Michigan Survey was in 1893[18] where on

[14] Bull. of the Sci. Lab. of Denison University, Vol. II, Part 2 (Granville, 1887) pp. 120-142.
[15] Univ. Comp. Zool. Vol. V, p. 280.
[16] Proc. Boston Soc. N. H. Oct. 19, 1881, p. 259.
[17] Geological and Natural History Survey of Minnesota, Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota, Bull. No. 2, M. E. Wadsworth.
[18] Report of the Board of Geological Survey.

page 90 he gives a classfication of rocks and on page 147 uses the term "clasolite" for a deposit of sediment in fissures. In 1897 he gave for the Lake Superior meeting of the American Institute of Mining Engineers a clear and interesting summary of his views on the "Origin and mode of occurrence of the Lake Superior Copper deposits," which was printed in their Transactions. (XXVII, 669.)

Bayley[19] in 1889-97 describes the Minnesota gabbros in some detail and also the Pigeon Point rocks. He found *non-feldspathic* varieties of *gabbro.*

Grant in 1893 and 1894, describes, for the Minnesota Survey, gabbro, diabase, granite and a marginal facies of gabbro. His *augite soda* granite is a *red rock* like Irving's augite syenite and granitells, or Bayley's soda augite granite.[20]

The work of Hubbard, Patton, and Lane began in Michigan in 1889-92. The first publication is in the 1892-3 report, though there the only Keweenawan rocks described under our own names were some diabases intrusive in the iron bearing rocks. We were fellow-students under Rosenbusch and have since worked in close relation. We have tried to use terms as they are used by earlier writers, and we have also tried to apply them so far as possible to the same things. It does not bother the practical man who has only incidental use for a geological report if a rock be called a *melaphyre,* whether stress is laid upon the fact that it is pre-Tertiary or effusive, or is older and contains chlorite and is altered, so long as the hanging wall of his lode is in each case called a *melaphyre.* We therefore continue to use the term *melaphyre* as applied to many of the Keweenaw traps.[21]

I did, however, begin to use one term which is not new, nor as I supposed new in the sense in which I used it, but is new in the district, viz. the term *ophite*[21] as a short equivalent for luster mottled melaphyre, applying it also to rocks which had the same texture as melaphyre, but on too fine a scale to give the luster mottling appearance, and I prepared for Volume VI, a table showing my usage.

To others of the traps, I applied geographic names in the Isle Royale report (p. 170) such as

Tobin porphyrite=Rosenbusch's navites?

Huginnin porphyrite=(a kind of diabase porphyrite).

[19] "Basic Massive Rocks of the Lake Superior Region" by W. S. Bayley, first three parts in Journal of Geology, Vol. I, Nos. 5, 6, and 7, fourth part in Journal of Geology, Vol. II, No. 8, and Vol. III, No. 1.

[20] Numerous papers listed in Bull. U. S. G. S., No. 188.

[21] Bull. Geol. Soc. Am. Vol. 8 (1896), p. 406 Vol. 10 (1899) p. 15. See also U. S. G. S. Monog. 52, p. 398; and Science Vol. XXXII, p. 513.

Minong Porphyrite=(akin to an augite andesite.)

I also prepared a field scheme.

Former Assistant State Geologist F. E. Wright, prepared for the Michigan College of Mines, a synopsis of Rosenbusch's classification of rocks which, though it was accompanied by no text, should nevertheless be considered, because so many of the mining men will have been by its use familiarized with its terms. The same statement also applies to the names used in Kemp's Handbook of Rocks and "Ore Deposits of the United States."

I have remained fairly faithful to the usage in Volume VI, prepared by Hubbard and myself. The only important modification from Rosenbusch's system introduced by me[22] was the attempt to confine the the two chemically synonymous terms, *diabase* and *melaphyre,* respectively to dike and effusive rocks, a proposition which Rosenbusch, though granting its desirability on theoretical grounds, has not accepted[22] for reasons which may be practically sound. A good deal depends on whether it really is practicable to separate the intrusive rocks from the coarser central parts of flows.

In 1903, appeared an important work[23] by a group of the leading American petrographers, which broke away entirely from previous names and made a host of new names, dependent on a complete chemical analysis, though there are methods given by which one may estimate from the chemical analysis the mineral composition of the rock, were it composed of certain standard minerals, and vice versa from the minerals actually present one may infer the probable place in the classification. The lines between the different subdivisions are arbitrarily drawn in the classifications and constituents like H_2O and CO_2 (which are liable to have been added in weathering, but are certainly in some rocks primary and are very significant genetically) are absolutely neglected; other constituents like ferrous and ferric iron, which are equally likely to be modified by weathering, are given much weight and some substances, which are hard for the chemist to determine accurately, are so important in the scheme that samples from the same rock mass apparently differing but little in composition will sometimes find pigeon-holes astonishingly far apart in the classification, without more difference in the analysis than may be due to analytical errors. Occasionally, therefore, there are rocks in the same group in the classification which have little or nothing

[22]Bull. G. S. A., 1893, p. 273, Michigan Geol. Sur., Vol. VI, Pt. 1, p. 220. See Mikroskopische Physiographie, fourth edition, Vol. II, pp. 1160-1161.

[23]"The Quantitative Classification of Igneous Rocks" by Cross, Iddings, Pirrson and Washington. (Hereinafter referred to as the "Big Four") Chicago University Press.

in common other than the bare chemical factors by which they are assigned to that group. All of this simply shows that the classification is not perfect. Few things are. The authors, however, suggest a series of names for field use which are convenient and very much like those which it has been customary to use.

§ 2. WINCHELL'S CORRELATION.

Winchell, with a labor for which I am very grateful (as it corrected some slips in an unpublished table which I had prepared for my own use), has calculated the pigeon-hole and the position under the Quantitative Classification of all the rocks of which we have trustworthy analyses, and has prepared a table of these names, as well as of the older names.[24] It will, then, be well first to go over his table II, slightly modified as herewith given a "Correlation of Nomenclature of Keweenawan igneous rocks," making some comments and comparisons. One thing must be remarked which will account for a good deal of the variety. *The same dike of lava or the same lava flow* may differ very widely in different parts and especially at different distances from the margin, so that it will be absolutely different in texture and quite different in chemical composition in different parts. One great difficulty has been in applying a name to a rock mass and then trying to define the name afterwards. The characteristics of one part will not apply to all parts of the rock. It seems to me, therefore, permissible for the field geologist to apply to a whole lava flow a name which by strict definition will apply only to some large part of it. If we do not do that we shall be driven to using some arbitrary geographic or proper name or number. This indeed we do to some extent and speak of the *"Kearsarge foot,"* Bed 87 of the Eagle river section, Arcadian flow 23, etc. But it seems to me it is a great help to comprehension and memory if we may also speak of the *Chippewa felsite*, the *Mabb ophite*, etc., without meaning thereby that the so-called *Chippewa felsite* may not frequently have more or less conspicuous phenocrysts and so be called more strictly a *feldspar* or *quartz porphyry*, or that the *Mabb ophite* may not be, at the very top, a glassy amygdaloid.

Going over the roll of names cited by Winchell we find that his use of the term *Granite* is agreed on by all. His use of the term *Quartz porphyry* is agreed to by all but A. N. Winchell, who would substitute *rhyolite porphyry*. The term rhyolite has not heretofore been applied to these rocks, though they are chemically

[24]Journal of Geology, Nov.-Dec. 1908, Vol. XVI, No. 8. Monog. 52, p. 400.

and in origin equivalent to the Western rhyolites, and many of them show beautifully the bands marking the flow lines. On this point W. H. Hobbs said in 1900:[25] "The tendency of American petrographers seems to be to abandon entirely terms of the class *quartz porphyry* and to extend terms correlated with *rhyolite* to cover rocks which were previously included in both groups. This tendency seems to me to be an unfortunate one since it results in classing together rocks which are essentially unlike. There may be no important difference between a particular *quartz porphyry* and a particular *rhyolite* but compare a drawer of hand specimens of the former with one of the latter and an argument is unnecessary to show that as a class they are essentially different. The *quartz porphyries* are as a class, devoid of vesicular and fluxion structures— they are in their method of occurrence hypabyssal—and they more generally show the effects of devitrification and weathering, etc." The authors of the Quantitative Classification, whom I shall hereafter refer to, for short, as the "Big Four," would keep the term *quartz porphyry* or *quartzophyre.* I should be tempted to confine the term *rhyolite* to porphyries in which lines of flow were a marked feature. *Felsite* becomes *rhyolite* for Winchell and Grant. Rosenbusch in his latest edition uses *quartzless porphyry* and *felsite* for the ground mass of a porphyry. It seems not inappropriate to continue to speak of porphyries in which the ground mass alone is conspicuous as *felsites*, and such is the usage of the Big Four for "non porphyritic, light colored, rocks."

Obsidian and *apobsidian* are terms applied by Winchell and Wright to certain Minnesota felsites. *Tuff* we all agree upon as a name for volcanic detritus. *Augite syenite* and *granitell* of Irving (the latter distinguished by having quartz), *granite* and *soda augite granite* of Bayley and A. N. Winchell and Grant and N. H. Winchell, are names applied to the *red rock* associated with the big gabbro intrusives. These rocks often occur in pebbles in the conglomerate. They correspond to my *augite syenite* or as I have called them, in accordance with my belief that they stand in the same relation to a gabbro as an ophite to a granite, *gabbro aplite.*[26] The typical thing is the dominance of red and plagioclase feldspar. They are fully described in Wright's paper.[27]

Quartz keratophyre and *granophyre* are terms in Rosenbusch's classification that have been widely applied to these rocks. Bayley found them applicable to some of his Pigeon Point *red rocks,* which

[25]Journal of Geology VIII, No. 1, p. 6.
[26]Report for 1903, p. 236; Vol. VI, Part II, pp. 72-3; Report for 1904, p. 153.
[27]Report for 1908, pp. 361-393.

he is inclined to believe are softened sandstones. The Big Four would dub them *syenites*. If there is really conspicuous quartz they would term them granite. Then such terms as *soda granite* and *soda augite granite* are fitting enough. Whether we need a term for both augite syenite and soda granite and whether *gabbro aplite* is a fitting one remains to be seen. The simple term *red rock* has also been used.

Felsite porphyry (Pumpelly) *felsitic porphyry,* (Irving), *felsite* (Hubbard and Lane), and *orthophyre,* (a technical Rosenbusch term, Lane), Winchell, N. H., Winchell, A. N., and Grant would call *trachyte.* The Big Four would class this rock as *felsite* or *feldspar porphyry* according as the feldspar phenocrysts were present or not. As a matter of fact, a good deal of the felsite almost free from phenocrysts will be found on careful examination to be feldspar porphyry or feldsparphyre. A *trachyte* for most writers is a modern glassy rock. These are not. The term *orthophyre* implies that the porphyritic feldspar is orthoclase, a thing that is is sometimes well to emphasize. Syenite or granophyre of Winchell and Grant, or *monzonite* of A. N. Winchell, is probably much the same as the *augite syenite* and granite and *granophyre* of other writers, because in this, the red rock group, the feldspars are always nearly balanced. *Augite diorite* and *melaphyre* of Pumpelly, *hornblende* and *orthoclase gabbro* of Irving, *hornblende gabbro* of Bayley, *gabbro aplite* (?) of Lane, *orthoclase gabbro* of A. N. Winchell, porphyritic gabbro of Winchell and Grant, which A. N. Winchell has bracketed together, form a rather heterogeneous group including, as near as I can judge, the very coarse centers of some flows, and perhaps some of the dike rocks that I should call *gabbro aplites,* but I have often noticed that next to them the rock in which they are injected is apparently more or less saturated with their magma. This may be the rock called *oligoclase gabbro*, and *orthoclase gabbro.* The Big Four would doubtless include them all in the term *gabbro,* but it seems hard to call the coarser center of a flow or a spot in the same a *gabbro* even though the augite crystals be two inches across, especially so long as the feldspars remain very fine. Such gabbros are different in appearance from the typical plutonic gabbro, such as the great Bad River gabbro that begins north of Bessemer and perhaps extends to Minnesota. It is not really difficult to distinguish between them. If one character fails to help, another will. The coarse effusive is more open textured and the original pores are coated with chlorite or filled with some secondary mineral which does not replace any

other mineral. Also, the feldspar and magnetite are often very much finer grained than the augite. With the exception of these few effusives,[28] this group is plutonic and corresponds apparently to the porphyrite and Ashbed type of effusive of which these rocks are the plutonic equivalent. Wright puts them down on the Quantitative Classification as *Bohemial auvergnose*. I have not located the reference by A. N. Winchell to Irving's *orthoclase diabase*. Probably it is some variety of the *gabbro*, *Bohemial auvergnose*. The real plutonic gabbro has feldspar better crystallized than the effusive, owing, I presume, to the retention of mineralizers by pressure. The *quartz diabase* of Bayley, Lawson,[29] Lane, Winchell and Grant, and numerous other writers since Wadsworth and Wichmann correctly described these rather small sized intrusives cutting the Huronian rocks is always intrusive, so far as the writer knows, and all agree in the nomenclature. What the writer calls *diabase* nearly every one would call *diabase*.[30] The *quartz diabase* is in no sense analogous to Diller's *quartz basalt*, where the quartz is in the form of corroded brotocrysts. *Enstalite* and *hypersthene diabase* is also, so far as I know, intrusive,— the Big Bay occurrence may be mainly hypersthene. No analyses have been made and it is hardly known in Michigan as a Keweenawan rock.

The advantage of narrowing the definition of a diabase so as to include only the typically small intrusives, as suggested by me in Volume VI, is that we include a nearly homogeneous group which nearly all writers have agreed to call *diabase*. I defined it as a "characteristically intrusive, not too coarse grained rock of the same chemical composition and essentially the same mineral composition as a melaphyre." The word "characteristically" is the ambiguous one. I think we might replace it now by saying that the rock is not glassy except very close to the margin, is not amygdaloidal and there are no cavities which show by concentric coatings of fibres of chlorite that they are the filled angular pores, originally filled only with gas or water, left in the contraction due to crystallization. The last mineral formed is either augite or quartz or feldspar or perhaps analcite, etc. The feldspar is coarse when compared with the augite and, generally within less

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[28] Irving classes the Eagle River bed 94 as an *orthoclasc gabbro*. But this is part of the big "Greenstone flow toward the top." I seriously doubt the presence of primary orthoclase.

[29] Minnesota Geological Survey, Bull. No. 8, 1893; Canada Survey, T. CC. 1886. 3F 1890; Canadian Inst: Proc. 5, 1886, p. 177-185; Am. Geologist Vol. I, 1886; pp. 199-211; Am. Geol. Vol. VII, pp. 153-164.

[30] Koch loc. cit. and Rominger Mich. Geol. Survey, IV, p. 145 use the term dolerite and so would Pirsson. If a *felsite* is to be called *rhyolite*, why not a diabase a *dolerite?*

than four feet of the margin, is plainly visible in lath-shaped crystals a millimeter long. In distinction from the typical gabbro, the feldspar is sharper than the augite which is not so large, and there is generally a distinctly finer grain near the margin which is particularly dense in the diabases. On the other hand in the typical gabbros the grain may be coarser at the margin and even when it is finer, it may have solidified originally as glass, and the grains seem to have afterward devitrified into a rather characteristic fine grained aggregate. It must be remembered, however, that very many other writers do refer to *amygdaloidal diabases*, and call *diabases* many of the rocks which I call *melaphyres*. Others call them *basalts*.

The terms quartz diorite and diorite are used by writers from Wadsworth on, and so far as I know in the same sense, though of course the line between them and uralitic gabbro will, at times, be hard to draw. It must also be remembered that igneous contact metamorphism changes augite to hornblende.

Anorthosite is a term used by Lawson (as A. N. Winchell forgets to note) for Minnesota occurrences[31] and by various Canadian writers. It is a Latinization of Irving's name *anorthite rock*. A. N. Winchell would replace it by the term *plagioclasite* because the feldspar is not always anorthite. But the anorthite molecule is largely present. As it does not occur in Michigan except in pebbles, so far as known, we do not have to decide the controversy. *Gabbro, diabase,* and *melaphyre, olivine diabase* and *ophite* is the rubric at which there is most variation in names. In the first place it may be noted that there is (I think) no essential difference in chemical character implied by these names, though in the chemical classification some are II, 423, Adamellose; II, 534, Andose; II, 535, Beerbachose; II, 5445, Hessose (many); III, 534, Camptonose; III, 5445, Auvergnose (most). This latter in the writer's judgment covers most nearly the normal composition of the group and Winchell in fact assigns ten analyses to it. Silica 45-49 per cent, Al_2O_3 about 16 per cent, CaO about 10 per cent, iron oxide 10-13 per cent. These are the fundamental factors.

There is, however, a variation in the amount of lime and soda. The very same flow will show a variation in different parts in which the calcium oxide will run from six to ten per cent; the part last consolidated runs higher in lime and seems to be thus nearer the eutectic. The potash, as will be readily seen in looking over the analyses, is always less than the soda and usually less than

[31]Minnesota Survey Bull. No. 8, 1893, pp. 1-23.

3 per cent. The soda varies somewhat in inverse ratio to the lime. The various places in which these rocks are found in the chemical classification are partly due to this variation, but are also quite possibly due to inaccuracy of analysis. A little change by which the alumina gains at the expense of the magnesia, or titanium oxide at the expense of the silica, makes a great difference in the classification, and even a change, which may be secondary, in the condition of the iron from ferrous to ferric has an important influence. For this part of the classification the Quantitative Classification fails to be a useful guide in grouping together the really important factors.[32] It seems, therefore, that it would hardly be wise for me in a report in some sense final to change the names heretofore used. I use the term *gabbro* for the deep-seated *intrusive* rocks in which the feldspar is usually as coarsely crystallized as the augite and both constituents are fairly coarse. The last interstices may be filled with quartz or rarely orthoclase or micropegmatite but are never empty. *Diabase* will be applied to the intrusive dikes and sills in which the feldspar is coarser than the corresponding feldspar in the effusives except in the doleritic type. The interstices are generally filled with augite but the last interstices or so-called acid interstices, which I have fully described,[33] may be filled with an intergrowth of quartz and feldspar known as *micropegmatite*. That the interstices were at one time filled with a hot solution which tended to react on the pre-existing minerals is quite plain. The doleritic type of the melaphyres differs from the diabases only in that the last interstices are more likely to be filled with concentric coatings of agate or chlorite and seem to have been very probably at one time gas-filled pores. There may have been some glass, but in the thicker part of the flows the chances are against the presence of residual glass and there are no signs of it.

Melaphyre is a term which I shall still apply, following the custom from Macfarlane down, to the flows which make up the great bulk of the Keweenawan series. The upper part is generally amygdaloidal, with gas bubbles filled by secondary minerals. There was, originally undoubtedly more or less glass, but this is now largely decomposed. Bubbles may occur anywhere in the flow and the exact width which one shall in different cases give the amygdaloidal portion is a very uncertain factor. It is not usually over five feet. When greater thicknesses are

[32] See "Natural History of Igneous Rocks" by A. Harker, MacMillan & Co. Also his review of the Quantitative Classification, Geol. Mag. 1903, p. 178.
[33] Vol. VI, Pt. I, p. 235.

given it will often be found that the whole of one small flow has been counted as part of the amygdaloid. The upper part of the flow being called *amygdaloid,* the central part will (following the miner's usage) be called *trap.* In this more compact and massive part the original characteristics of the flow are often more distinct than in the upper part, where secondary decomposition has often gone on to a very considerable extent.

The division of the melaphyres into groups is made largely upon the basis of the appearance of the trap. In the first place, there may be large crystals of feldspar which seem to indicate that the hot lava from which the melaphyre came had started to crystallize under conditions of very slow crystallization and very possibly before eruption, so that the crystals are intra-telluric. Such rocks Rosenbusch would call (if the feldspar is labradorite as is often the case) *labradorite porphyrite* and Kemp and Pirsson would call them *basalt porphyry,* and in some cases, perhaps, *dolerite porphyry.* Streng called them *melaphyr porphyr.* The Kearsarge foot is one of the most characteristic of these labradorite porphyrites (see Pl. 7, core from Mandan drill hole 18 at 90 feet), but similar rocks are also found abundantly toward the base of the series, both in the Bare Hill district on Keweenaw Point and also on the Gogebic Range where they are found just north of Bessemer and may be traced west into Wisconsin and east past the south end of Lake Gogebic. They may be found also in the Porcupine mountains.

There is another kind of porphyritic texture which occurs especially toward the top of many of the flows. There are in this little crystals of feldspar, generally not more than one or two millimeters long, whereas the kind of which we have just been speaking are several millimeters in length and sometimes several centimeters, even an inch, in length. These crystals are frequently aggregated or one might almost say clotted like curdled milk. I have called this texture *glomeroporphyritic.*[34] It may be seen in studying a series of drill cores from the same flow (cf. Plate VII), Ss. 15295 and 15384) that from a distinct glomeroporphyritic texture at the top the rock may pass into an even grained texture at the middle or there may be at the middle a tendency to mottling due to the occurrence not of patches of augite but of patches of feldspar which have grown together. The texture I have called the glomeroporphyritic seems to be associated with an extra amount of soda. I do not think it is due to an intra-telluric stage of crystal-

[34]Vol. VI, Pt. I, p. 167.

OPHITIC TEXTURE DEVELOPING AND POCK MARKED APPEARANCE AT THE CREST OF THE BLUFF OF THE OLD DELAWARE MINE, IN THE GREENSTONE NOT FAR FROM THE LINE OF MANITOU CROSS-SECTION (FIG. 29) BEING BACK OF THE OLD DELAWARE MINE. TAKEN BY W. J. PENHALLEGON, AUGUST, 1907. THE WHITE OBJECT IS A SLIDE RULE SIX INCHES LONG AND ONE INCH WIDE AND THE EXPOSURE IS ABOUT 100 FEET FROM THE BASE OF THE GREENSTONE. REPRODUCED FROM THE BULL. GEOL. SOC. AM., VOL. 18, 1906, PLATE 71. SEE ALSO REPORT FOR 1908.

lization, that is to say, that these crystals started to form deep within the earth and their formation was interrupted by the volcanic outburst, but rather that the presence of so much soda tended to promote their crystallization in the shape of andesite feldspar before the eutectic in the final cooling, and before the lava came entirely to rest, perhaps, at any rate at an early stage of crystallization. It is thus a chemically significant texture. It may be found in various parts of the series, but it is especially characteristic of the Ashbed group above the Greenstone. This group I called in Volume VI the *Tobin porphyrites*. They are very close to Rosenbusch's *Navite family*. (See Pl. VII, Ss. 15295 and 15384.)

The final goal toward which these lavas seem to have tended in crystallizing, that is the most fusible and the last crystallizing residue, is at the same time a most common independent type. Apparently, at an early stage there was a tendency for olivine to form, but at a later stage (probably at a lower temperature when augite could form) augite has taken the place of the olivine which has been reduced to corroded remnants and has been crowded ahead of the patches of augite. The feldspar is a labradorite and lime soda feldspar of a composition near Ab_2 An_3 which seems not to have crystallized as soon as the temperature fell to the point where it might have done so, as it does not become as coarse in proportion in the center as the augite. Still it precedes the augite and magnetite. The last thing to crystallize seems to have been the augite and the composition of the rock as a whole is not far from that of augite, nor is it far from that of Bunsens normal basaltic magma. (Table IV, and Fig. 12.) The result is that relatively small feldspars lie in a ground mass which is a cement or matrix of augite. In the coarser part of the flow the augite is so coarse that very many feldspar crystals are imbedded in one augite crystal. Toward the margin the augite is finer, so fine that a granular aggregate of several grains of augite may make up the interstices between the feldspar (which mainly occurs when there is a sort of transition to the glomeroporphyritic type at the top of the flow when the center is typically ophitic.) This is the structure which I have called *ophitic* and I have called the melaphyres which show this structure *ophite*. Winchell[85] is inclined to object to this. The question is discussed in the next chapter. The rocks are precisely those described by Pumpelly and Marvine who noticed the flashing due to the augite cleavages when the texture is sufficiently coarse and called them *luster mottled melaphyres*.

[85]Bull., Geol. Soc. Am., Vol. 20, p. 661. U. S. G. S. Monog. 52, p. 398.

Finally, never as an independent rock, so far as I know, there are spots or streaks or sometimes long bands in the larger flows of melaphyre where the feldspar is much coarser, in fact all the crystallization is much coarser. The probabilities are that these occur where the mineralizers of the original magma were concentrated. They might be called *rudimentary pegmatites*. The feldspar is in all cases much coarser and sharply crystallized. The augite is also not infrequently distinctly crystallized, although its growth is more or less interfered with by the feldspar. Other crystals, such as magnetite, hematite and ilmenite also appear. The interstices last formed are commonly filled by chlorite in concentric coatings, as though it had filled cavities and it is these places that I have called *doleritic spots, doleritic melaphyre,* etc. Sometimes certain whole flows have an exceptionally strong tendency to this type of texture. The doleritic streaks appear in numerous places. In all such cases the feldspar, owing to coarser crystallization, is more conspicuous; whether there is really more feldspathic material in the rock I am by no means sure. I used the term *dolerite* because as generally used it implied coarse feldspar. If the term *dolerite* is to replace *melaphyre* or *diabase* as some have suggested, it may be better to call these *pegmatitic melaphyres.*

The above will, perhaps, give one some idea of the way in which names are used in this book. It is a common fault of the young student in reading older reports, such as those of Douglass Houghton or Hubbard to consider that they did poor geological work because they do not use the terms in the sense in which he has been accustomed to use them. It is unfortunate, but it seems unavoidable that with the growth of our knowledge the concepts which we imply by different words must somewhat vary and so it is always well to be careful in reading an author that one knows in what sense he uses terms. In the earlier geological reports it was very common to give at the end a little glossary or dictionary. The abundance of excellent encyclopedias and dictionaries have made this apparently unnecessary in geology, but just at present in petrography we are in the transition stage and are obliged to revert to the original usage.

§ 3. THE NOMENCLATURE OF THE SEDIMENTARY ROCKS.

The sedimentary rocks bear a strong resemblance to the rocks of the Permian and Triassic periods to which they were originally referred. They are prevailingly conglomerates and sandstones. The sandstones even include a great variety of grains of different

sizes which are by no means wholly quartz. The sandstones are really fine grained conglomerates. There are other rocks of still finer grain,—red muds and shales which occur as streaks in the conglomerates. Sometimes these contain considerable white mica. This is of importance because J. Barrell has recently pointed out the the climatic significance of white mica in rocks of this nature.[36]

These red shales often contain ripple marks and mud cracks. I have not seen anything that I can call with certainty rain prints. There are here and there other curious markings like tracks such as those figured on Plate V. The Nonesuch formation is characteristically dark gray or black instead of red. This color is not caused by carbonaceous matter but by chlorite or iron ore. In fact, certain pieces of these rocks are as shiny with specular hematite as some of the black sands which one can now pick up along the shores of Lake Superior. This kind of black shale, therefore, which may be considered a characteristic rock of the Nonesuch formation, is not to be likened to the Devonian black shales or those of the Animikie beneath. In the region around Thunder Bay dolomites and dolomitic marls have been reported from the Keweenawan, but with these I am not familiar and A. W. G. Wilson tells me that their Keweenawan age is not certain.

In the conglomerates three or four distinct types can be recognized. In the first place there is the ordinary conglomerate with well rounded pebbles and a sandy matrix. In the Great conglomerate the size of the pebbles is somtimes very great and they are not assorted, yet the matrix is not clayey and on the whole they resemble much more the conglomerate found in gulches or *arroyas* in the west or a beach exposed to heavy storms than till. From these coarse conglomerates there is every gradation down to the finest and there are fine streaks of conglomerate in the sandstone and of sandstone in the conglomerate. Usually these conglomerates contain very little material except that supposed to be derived from the Keweenawan formation. The porphyries are conspicuous among the pebbles. Yet where the Keweenawan formation approaches the old land masses, for instance, north of the Gogebic Range, pebbles of jaspilite from the iron ores and granite are common. So, too, the conglomerates at Mamainse contain a very large number of "Laurentian granites" and green "Huronian" pebbles which may be referred to the older rocks which lie a short distance further inland.

A second type of conglomerate, of which the Calumet and Hecla

[36]Journal of Geology, 1908, p. 268.

conglomerate is the most notable example, is composed almost exclusively of pebbles, and these of such extremely angular type that the rock has often been called a *felsite breccia.* Credner suggested[37] that this "bed of felsite breccia represented the upper end —the cap—of a felsite porphyry injection which had penetrated beneath the beds of the melaphyre amygdaloid following the same surface of separation, had consolidated on its way in part and then had been shattered by the fluid rock pressing behind and enclosed by the same." He expected that further opening of the Calumet and Hecla mine would show a transition of the breccia into a massive felsite porphyry and that perhaps the point would be found where it would appear as a dike crossing the bedded rock. This expectation has not been realized for the conglomerate as it is followed passes into other types of more common sedimentary conglomerates. If, however, he had left out the word "enclosed" and supposed that it were derived from the shattering of a superficial projection like the spine of Mt. Pelee, which, of course, had not come into existence at the time he wrote, there would have been something to be said in favor of his view, for beneath the Calumet and Hecla conglomerate to the southeast on the property of the Torch Lake Company a quartz porphyry has been found which seems to be truly intrusive and there are also felsites and this quartz porphyry appears to be the source of very many of the pebbles of the Calumet and Hecla conglomerate, although it is not uncommon to find pebbles of other types and more rounded forms belonging to more basic and softer beds. It seems on the whole best to explain these breccias by the well-known tendency of felsites to break up into angular blocks. Anyone who has attempted to trim out a good sized specimen, knows how difficult it is to get one of any size owing to the tendency to break up into angular pieces. If we suppose that the conglomerate is due largely to weathering and has not been transported very far this will account for the angularity of the breccia and this is what seems indeed, to be the case, for within two miles of the Calumet mine proper, the conglomerate has changed its looks entirely and passed into the next type which we shall consider,—the amygdaloid conglomerate. This transition was also found, I am informed, in part of the workings of the Tamarack Junior.

The third type of conglomerate is that which has been sometimes called *Ashbed* and which was called by my predecessor, Dr. Hubbard, *amygdaloid conglomerate.* On the whole for popular use the

[37] N. Jahrbuch f. Min. 1869.

latter seems to be a satisfactory name because it gives at once its characteristic feature. It is a bed of conglomerate in which the pebbles are amygdaloidal. (See Pl. II B and Sp. 20485 of Pl. VII.) The matrix is generally a red, fine grained material which may be to some extent decomposed ash and to some extent decomposed melaphyre. In some places the fragments of amygdaloid appear to be derived by erosion from the top of an amygdaloid bed, but in many cases,—in fact I think most cases, they appear to be rather scoriaceous—the irregular, rough, open clinkery blocks of the upper part of a bed of lava of the aa type. In many cases, indeed, these pass down into an underlying bed so gradually, and the red matrix which cements the conglomerate proper may extend into cracks into the underlying lava so far that if one is studying drill hole samples only it is impossible to tell where the amygdaloid conglomerate ends and the lava underneath begins. For this reason I called them in Volume VI of my report *scoriaceous conglomerate* and the name tuff is not unfit, but as they occur so often in connection with the amygdaloids and as a given lode may in one place be an amygdaloid and elsewhere assume the appearance of amygdaloid conglomerate there are some advantages of continuity in names in using the term *amygdaloid conglomerate* which I shall therefore retain. This is especially true because some of the earlier writers seem to have lumped together the amygdaloids and amygdaloid conglomerates and the gradual transition from one to the other is the reason why many were inclined to think that the amygdaloid itself might be some sort of metamorphosed sediment.

In a few cases I have seen beds in which most of the bed or a good part of it was this fine red shale which may have been originally red mud but was mixed with an amygdaloid of a peculiar type extremely full of bubbles, so much so that it seemed derived from a pumice, fragments of which can easily be imagined to have floated along with the stream and settled, becoming thus scattered through the red bed of fine material. In the Victoria mine crosscut there was a fine opportunity to study such conglomerate. I have felt the need of a somewhat different term than either of the terms previously used, and so I have used the term *pumiceous conglomerate,* really a highly amygdaloidal conglomerate with a great deal of cement. It must be of course, understood that as with all sedimentary beds these different beds are very likely to pass into each other and to show every gradation. At the same time a peculiar lithological character may be characteristic of one bed for a considerable distance.

SUMMARY OF KEWEENAWAN ROCKS ACCORDING TO QUANTITATIVE CLASSIFICATION.

I.—1. 3. 1. 2.
Magdeburgose.
1. 3. 2. 3.
Tehamose.
1. 4. 1. 1.
Lebachose.

Felsite, Keweenaw Point, Michigan.

Hubbard, 1898.

I.—1. 4. 1. 3.
Liparose.
1. 4. 2. 3.
Tuscanose.

Granite, Soda Granite, Quartz Keratophyre, Pigeon Point, Minn.

Bayley, 1889-95.

I.—1. 5. 4. 4. 5.
Labradorose.

Plagioclasite, Carlton Peak, Minn.

A. N. Winchell, 1900.

II.—4. 2. 3.
Adamellose.

Gabbro (?)

Pigeon Point, Minn.

Wadsworth, 1887.

Quartz Diorite, Pigeon Point, Minn.

Bayley, 1889-95.

II.—4. 3-2. 4.
Tonalose-dacose.

"Red rock dike." Mt. Bohemia, Mich.

Lane, 1905-06.

II.—5. 1. 4.
Umptekose.

Felsite porphyrite, Keweenaw Point, Mich.

Hubbard, 1898.

II.—5. 2. 4.
Akerose.

Porphyrite, Keweenaw Point, Michigan.

Hubbard, 1898.

II.—5. 3. 4.
Andose.

Hornblende gabbro, Duluth, Minn.

Streng, 1877.

Melaphyre, Middle Bed 87 Eagle River section, Mich.

Pumpelly, 1878.

Porphyrite, Isle Royale, Mich.

Lane, 1893-98.

Orthoclase gabbro, Duluth, Minn.

A. N. Winchell, 1900.

II.—5. 3. 5–4.
Beerbachose Andose.

Melaphyre porphyry, Duluth, Minn.

Streng, 1877.

Gabbro, Baptism River, Minn.

Wadsworth, 1887.

II.—4–5. 3. 5.
Placerose Beerbachose.

Quartz gabbro, Little Saganaga Lake, Minn.

A. N. Winchell, 1900.

II.—5. 3. 5.
Beerbachose.

Porphyrite, Isle Royale, Mich.

Lane, 1893-98.

II.—5. 4. 4. 5.
Hessose.

Diabase, Fond du Lac Mine, Douglas county, Wis.

Sweet, 1880.

Olivine, gabbro, Pigeon Point, Minn. & T 61 N., R 12 W., Minn.

Bayley, 1889-1895.

Porphyrite, Ophite, Isle Royale, Mich. Diabase granophyrite, Cleveland Mine, Keweenaw Point, Mich.

Lane, 1893-1898.

Olivine gabbro, Birch Lake, Minn. Diabase, Birch Lake Minn.

A. N. Winchell, 1900.

III.—4. 3. 4.
Vaalose.

Diabase granophyrite, Cleveland Mine, Keweenaw Point, Mich.

Lane, 1893-1898.

III.—5. 3. 4.
Camptonose.

Melaphyre, Bottom of bed 87, Eagle River section, Keweenaw Point, Mich.

Pumpelly, 1878.

Orthoclase gabbro, Duluth, Minn.

A. N. Winchell, 1900.

III.—5. 4. 4. 5.
Auvergnose.

Melaphyre, Lower part bed 64, Eagle River section, Keweenaw Point, Mich.

Pumpelly, 1878.

Diabase, Sec. 13, T 47 N., R 46 W. Gogebic Co., Mich.

Van Hise, 1892.

Gabbro (granular), Bashitanaquab Lake, Minn.

N. H. Winchell, 1893.

Olivine gabbro, Birch Lake, Minn. Gabbro, T 46 N., R 8 W., Minn.

Bayley, 1889-95.

Troctolite, Duluth, Minn.
A. N. Winchell, 1900.

Diabase, Lighthouse Point, Mich.
Ophite, St. Mary Mineral Land Co., Keweenaw Point, Mich.
Ophite Mt. Bohemia, Mich.

Lane, 1905-6.

IV.—1^1. 1^1. 2.
Cookose.

Hypersthene gabbro, Gunflint Lake, Minn.

Bayley, 1889-1895.

§ 4. METHODS OF STUDYING CHEMICAL RELATIONS.

(1) *The Quantitative Classification.* As we have above mentioned, some years ago there was prepared by a group of leading American students of rocks a system of classification dependent solely upon chemical composition. As A. N. Winchell[38] has recently determined according to this classification the position of all the Keweenawan rocks of which chemical analyses have been made, it will not be necessary for me to repeat his work. I have, however, summarized his table, and since many who read this report will not have the definitions of the different terms at hand we repeat them from the original publication in so far as it is necessary to make clear the relations of the different Keweenawan rocks.

CORRELATION OF NOMENCLATURE OF KEWEENAWAN IGNEOUS ROCKS WITH QUANTITATIVE CLASSIFICATION. AFTER A. N. WINCHELL.

All rocks are in Subclass 1 for which corundum and zircon $<$ 1-7 of the rock.

CLASS I. "Persalane." Quartz and feldspar $>$ 7-8 of rock.

Order 3. Quartz $>$ 3-5 of feldspars but $<$ 5-3.

Rang 1. "Peralkalic," alkalis $>$ 7 CaO.

Subrang 2. "Dopotassic." $7 > K_2O : Na_2O > 5:3$.

"*Magdeburgose*" = felsite J. Hubbard, p. 28.

Rang 2. "Domalkalic," alkalis $<$ 7 CaO but $>$ 1.6 CaO.

Subrang 3, Sodipotassic $5:3 > K_2O : Na_2O > 3:5$.

"*Tehamose*" = Mt. Houghton felsite 17193 A, Hubbard, p. 42, silicified.

Order 4. "Britannare," quartz not so high, 3 : 5 $>$ Quartz : Feldspar $>$ 1 : 7.

Rang 1. "Peralkalic," "Liparase." $K_2O + Na_2O > 7$ CaO.

Subrang 1. "Perpotassic" $K_2O > 7$ Na_2O "*Lebachose,*" felsite No. 16951.

Subrang 3. Sodipotassic. K_2O between 1.6 and 0.6 Na_2O.

Liparose Pigeon Point soda granites and keratophyres of Bayley.

Cf. Mt. Bohemia red rock and gabbroaplite.

Same Subrang but Rang 2 (domalkalic-alkalis) between 7 and 1.6 CaO.

"Toscanose" another of Bayley's keratophyres.

Order 5. "Canadare." 7 quartz $<$ feldspar.

Rang 4. Docalcic, "Labradorase." CaO between 1.6 and 7 alkalis.

Subrang 3. Presodic, *Labradorose*, $K_2O < 0.6$ Na_2O, Winchell's Plagioclasite or Lawson's Anorthosite.

[38]Journal of Geology, Vol. 16, No. 8, Dec. 1908, p. 765. U. S. G. S. Monog. 52, p. 395.

CLASS II. Dosalane and Dosalone quartz and feldspar > ⅞ of rock.

Order 4. "Austrare" quartz between 3-5 and 1-7 of feldspar.

Rang 2. Domalkalic, Dacase alkalis between 7 and 5-3 of CaO.

Subrang 3. Sodipotassic *Adamellose*. Pigeon Point red rock. Bull. 109, U. S. G. S., p. 56.

A quartz diorite produced as a contact effect of a gabbro intrusion?

Same but Rang 3 or 2, Subrang 4 dosodic. Mt. Bohemia *Tonalose Dacose* of Wright, a red rock also associated with gabbro. ("Wet eutectic" ?).

Order 5. "Germanare." *All subrang 4 or* 5 dosodic $Na_2O > 5 : 3\ K_2O$ or persodic $> 7\ K_2O$.

Rang 1. Peralkalic Umptekase and Umptekose, Felsite Porphyrite G Keweenaw Point, Hubbard, p. 26, 17039, 17007.

Rang 2. Domalkalic Monzonase and Akerose Porphyrite, Hubbard p. 25, Bed E, diabase porphyrite, Irving, pretty near Ashbed type.

Rang 3. Alkalicalcic, alkalis between 1.6 and 0.6 of CaO Andase and Andose, Isle Royale, p. 215, Nos. 15515 and 15519, Lane; and the Duluth hornblende gabbro, Streng; and Winchell; Eagle River 87 Ashbed type.

Subrang 5 to 4 Dosodic to persodic, andose or beerbachose Duluth melaphyre—porphyrite of Streng, N. J., 1877, pp. 48—117 and Baptism River Gabbro, Minn. Bull. 2, pp. 75-79.

On the line between Order 4 and 5, placerose—beerbachose, rang 3, subrang 5. Quartz just about 1-7 of feldspar, alkali calcic persodic. Quartz gabbro of Little Saganaga Lake, Minn. A. N. Winchell, Am. Jour. Sci., XXVI, 1900, p. 374.

Order 5, rang 3 subrang 5 beerbachose Isle Royale porphyrite (Ashbed or melaphyre porphyrite) 15537, same bed as the "Hessose" 15533.

Rang 4. Docalcic Hessase and Hessose.

Subrang 3 Presodic, $Na_2O > 5\text{-}3\ K_2O$.

Diabase Sweet, Wis. III, p. 350. Douglas Co., Wis; Quartz diabases, Sharpless, Mich., 1892, pp. 134-141; Pigeon Point Gabbro, Bayley, p. 61, and Jour. Geol. I, p. 712; porphyrite 15533, ophite 15523.

Olivine gabbro and diabase, Birch Lake, Minn., A. N. Winchell, Am. Jour. Sci., 1900, p. 374.

Typical Keweenawan melaphyres are just about on line between Hessose and Auvergnose.

CLASS III. Salfemane and (subclass 1) salfemone. with one doubtful exception[39]

also *all of Order* 5, i. e. Quartz 1 : 7 feldspar, *all 4* dosodic or presodic.

Rang 3. Alkalic calcic.

Order 4. Vaalare quartz > 1-7 but 3-5 feldspar.

Vaalase and *Vaalose* diabase granophyrite, i. e. quartz diabase, Sharpless, 1892, p. 134.

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[39] A slight increase in alumina, within limits of analytical error would bring it into Order 5 and perhaps into the Hessoses.

Rang (2 or) 3.

Subrang 4. (*Kilauose*) *Camptonose*.

Ashbed diabase Bed 65, Eagle River, Steiger for A. N. Winchell. Jour. Geol. 1908, p. 772.

Rang 3. Duluth orthoclase gabbro *basic part* by A. N. Winchell and bottom of Bed 87, Eagle River. Cf. andose by Steiger.

Rang 4. *Auvergnose* most common type ophites "dry eutectic"?, Mt. Bohemia, St. Mary's Core, Greenstone by Steiger, and Duluth Troctolite for A. N. Winchell, J. G., 1900, p. 374; lower part Bed 64 (? Pumpelly), Lighthouse Point and other diabases.

CLASS IV. Dofemane. feldspar $< 3 - 5$ but $> 1 - 7 - 1 - 1$ of rock.

Subclass 1. P(yroxene), O (livine) M (agnetite) $> 7 - 1 - 1$ of rock (patite.)

Order 1. Hungarare Pyroxene and Olivine $7 >$ iron ores, Minnesotiare.

Rang 1. Permirlic. $CaO + MgO + FeO > 7\ Na_2O$.

Section 1 Permiric $MgO + FeO > 7\ CaO$.

Subrang 2. Domagnesic. $MgO : FeO < 7 > 5\text{-}3$.

Cookose. Hypersthene gabbro by Stokes for Bayley 7036.

(2.) *Osann's Chemical Classification.* It may be advisable also to give some account of the latest and most elaborate German classification, especially as Prof. A. Osann of Freiburg, the author, has named one of his types of gabbro the *Keweenaw type,* although curiously enough by some oversight, analyses 159 and 160 which are the same as 8786 and 8589 of Bayley's paper[40] are not really "from the Keweenaw peninsula," but rather from the Keweenawan of Minnesota.[41]

Professor Osann's chemical classification is found in a series of papers.[42] For his purpose he divides the analyses of the rock up into molecules. This is, indeed, the method adopted by almost all writers treating of the subject. He excludes the water and carbon dioxide as probably secondary, then adding up the figures obtained by dividing the percentage of the molecular weights of the different molecules obtains a number which is usually not far from 1.5. Dividing by this number and multiplying by 100 one obtains numbers which represent the percentages of the different molecules or atomic groups into which the rock may be divided. The silica, with whatever little titanium and zircon may be there, he represents by a small s, the alkalis, mainly soda and potash by A. Subtracting from the alumina an amount equal to the alkalis gives a residue which is supposed to be combined with lime. It is called C. The balance of the lime and all the rest of the molecules of elements not already mentioned are grouped as F. Inasmuch as to

[40] Journal of Geology, Vol. 1, p. 712.
[41] Journal of Geology, Vol. XVI, p. 774.
[42] Tschermak's Mineralog. und petrographische Mittheilungen. XIX, XX, and XXI.

every molecule of alkalis and all the molecule C there is a molecule of alumina as well as one of base, we find that all the molecules of the rock may be summed up in the expression $s+2A+2C+F=100$. Then for plotting he used trilinear coordinates like those of Fig. 13 and a, c, f, which stand in the same relation to each other as A: C: F. but are diminished so that $a+c+f=20$. He also uses two other symbols. Of these n is the ratio of soda to potash. Finally if we suppose that the molecule A is all used up in orthoclase or albite (Na, K) Al Si_3 O_8, and the molecule C in anorthite Ca Al Si_2 O_8, and that the rest of the molecules have at least one of silica we find that it will take $6A+2C+F$ of silica to combine with these other molecules in the various minerals. This, however, is not in reality strictly the case, for in most rocks there is some iron combined as hematite and magnetite. Nevertheless the ratio of the amount of silica present to the sum given gives one a pretty fair idea whether the silica is much more or much less than the amount required to turn basic molecules into the minerals of the silicate family in which they most naturally occur. Consequently he denotes the ratio of $s:6A+2C+F$ by k. It will be recognized at once that there is a certain general resemblance in Osann's and the Quantitative Classification. Roughly speaking, f and F will be proportional to the femic constituents of the Quantitative Classification; k will have some relation to the different orders of the chemical classification. The ratio of A:C corresponds to the rangs therein and the ratio n to the subrangs. The dominant type of the Keweenawan basic rocks, which is also by far the most wide spread, is what Osann calls the Keweenawan gabbro type. The type formula (Fig. 13) he gives s_{51} a_1 c_5 f_{14}. For Bayley's analysis 8786,—the normal gabbro which is so wide spread in Minnesota,—the formula

is $s_{50 \cdot 80}$ $A_{2 \cdot 45}$ $C_{11 \cdot 00}$ $F_{22 \cdot 21}$ $a_{1 \cdot 5}$ c_6 $f_{12 \cdot 5}$ $n_{9 \cdot 1}$.

It is interesting to notice how closely this corresponds to the formula of the backbone of Keweenawan Point,—the Greenstone and the St. Mary's core ophite (Sp. 20618, Pl. VI) is not very far from the Keweenawan type, being $s_{52 \cdot 2}$ $a_{2 \cdot 3}$ $c_{6 \cdot 5}$ $f_{11 \cdot 13}$. His effusive types that have a and f similar, like the Rogat or Macomer type have slightly more silica.

Of course, all these different classifications, while they have value as systems of pigeon-holes enabling us to find similar analyses by different authors, have back of them also the desire to express the chemical relationships and these can often be best given graphically. (Figs. 12 and 13.) Other methods of writing the composition of

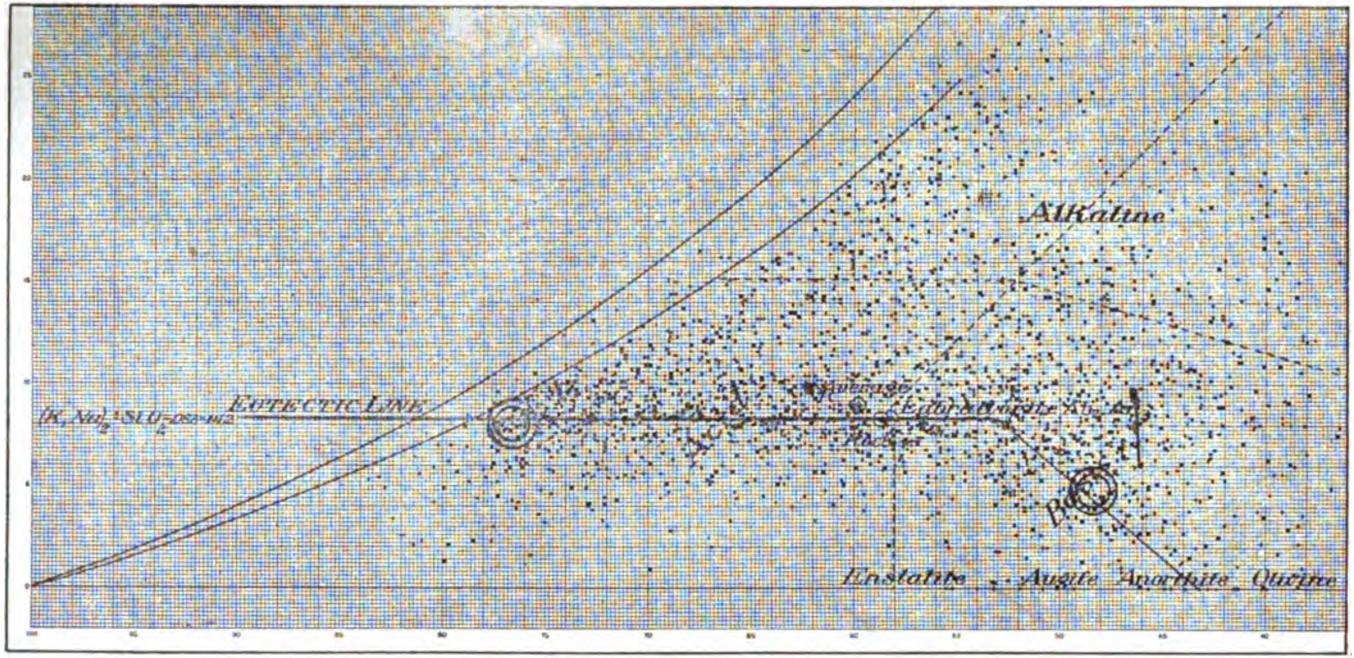

Fig. 12. Diagram 45 from Iddings. See also Jour. Geol. Vol. 12, page 91. The abscissa are percentages of silica running down to the right. The ordinates are the ratios of the molecules of alkali to the molecules of silica. Dots represent numerous analyses collected by Iddings. The double circles have for their centers respectively the normal trachytic and the normal pyroxenic magma of Bunsen. The apex of the V marks the position of Vogt's quartz feldspar eutectic. The square marks the oligoclase aplite. The line near 46% silica connects the ratio for lime melaphyres or ophites with that for soda melaphyres.

a rock in condensed form have been proposed notably by Levy and Becker. Some of Levy's are exceptionally ingenious but as the forms are rather complex for the printer I have omitted to summarize them here. The use of diagrams to express the composition of the igneous rocks has also been a matter of development. Probably the best plan is that of Brögger as modified by Levy, Hobbs and Iddings. Both Iddings and Osann also express the chemical relation of the rock by reference to a system of co-ordinates (Figs. 12 and 13) and then to express the minor factors Iddings adds a diagram whose center is determined by the co-ordinates. Almost all such attempts use the silica, which is the largest constituent in all the rocks we are considering, as abscissa. Iddings uses the molecular ratio of alkalis to silica for the ordinate. The position of some of the Keweenawan rocks on Idding's plan is shown in Fig. 12.

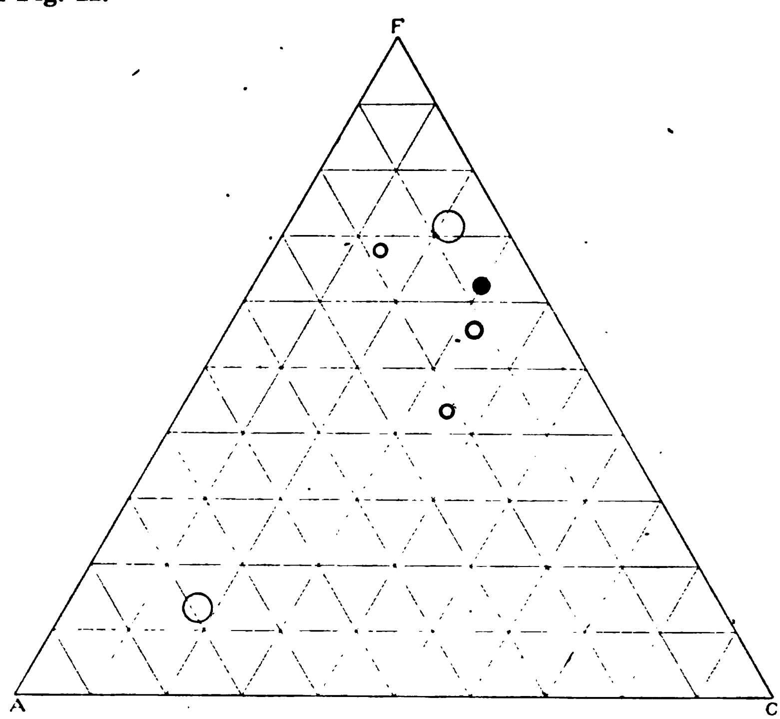

Fig. 13. Illustrates Osann's method of plotting analyses and their relations to albite or orthoclase (Lower left hand corner A), anorthite (lower right hand corner C), ferro-magnesian minerals (at the vertex F). The center of the circle is determined by the ratio of A:C:F in the analysis. Given in order from apex they represent:

Bunsen's normal pyroxene magma.
Analysis of 15515, a sodic melaphyre.
Osann's Keweenawan type of gabbro.
A lime melaphyre or ophite. 20618.
The red rock of Mt. Bohemia described by F. E. Wright as an oligoclase gabbro aplite.
Bunsen's normal trachytic magma.

It will be noticed that the commonest types, the ophites, are not very far from the central values given by the diagram.

Osann in his diagrams (cf. Fig. 13) locates the position of the dot representing the rock by the ratio of A:C:F. In both diagrams the granites are found in the lower left hand part but in Osann's diagrams the extremely femic rocks are at the top whereas in Idding's diagrams they are at the lower right corner. The divergence of what may be called extra alkaline rocks from normal alkaline rocks is not as well shown, perhaps, in Osann's diagrams.

§ 5. FAMILY RELATIONSHIP OF KEWEENAWAN ROCKS.

The subject of consanguinity has been lately of much scientific interest. By consanguinity is meant the relationship between different rocks due to their derivation from the same molten mass. In studying the consanguinity of rocks it is best to group the analyses in some of the diagrams mentioned above, and determine which components vary most widely and the nature of the variations. We find that certain oxides are co-variants. They probably occur in one molecular compound in the rock magma. Other relations are relatively invariant throughout the group. The invariant relations are the marks of consanguinity. Still other oxides will be found to be complementary. The chemical differences between them in these cases may be due to the fact that one represents a part of the magma which crystallized before the other, due to its lower fusibility. Secondly, differences may be due to the settling of the heavier molecules under the action of gravity either before or after they crystallized out. This seems to account for the marked differences in composition in many of the lava flows where the lower part is darker and less feldspathic than upper parts. Thirdly, the differences may be due to the absorption and solution of material from the adjacent rock, i. e., assimilation. I have often wondered if some of the melilite basalts were not produced thus, by the assimilation of limestone, since melilite is largely produced in the slags formed in smelting copper where limestone is added to the ground-up melaphyre. None of the Keweenawan rocks seem to have over 13 per cent of calcium oxide. The melilite rocks commonly exceed this. R. A. Daly has given us some most suggestive facts in this direction and, if we accept the results reached by Bayley, in fusion and absorption was the origin of some of the rocks at Pigeon Point—rocks not unlike those found at and near Mt. Bohemia.

One thing to which Harker[43] calls attention is well worth noting.

[43] "Natural History of Igneous Rocks," p. 118.

If rocks have any such serial relationship, their relation can be expressed by a diagram (such as Fig. 14) in which some one constituent is taken as an ordinate and all the others as abscissas whose ends will form a continuous curve. If, for example, any series of rocks is made by different mixtures of two types, as for instance, Bunsen's normal trachytic and normal basaltic magma (Table 4, Nos. 1 and 3, Figs. 13 and 14) or if they are made by the gradual separation into two types, or if they are made by the solution of one kind of rock, say of quartzite, by one kind of magma, we should find fairly straight lines. If, on the other hand, more than two different kinds of rocks or splitting actions had been concerned, we should not find the same regularity. The mixtures of three rocks could, however, probably be expressed by a continuous surface.

It will appear from the tables of analyses[44] that, on the whole, the Keweenawan igneous rocks as shown by these analyses are consanguineous,—belong to one family which probably extends more widely than might at first be thought, since if we compare these analyses with analyses from the Cobalt region we find very great similarity. Among the characteristic features may be noted the following:[45] The soda dominates over the potash except in the extremely siliceous rocks and the potash is remarkably low. Free quartz is not abundant and so in classes 1, 2 and 3 rocks of order 5 dominate rather than 4. There is no extra aluminous rock such that the alumina can not be combined with the alkalis and lime nor are there any ultra alkaline rocks. The *iron is decidedly high.* Is this connected with absorption from the iron formations beneath? In many respects they approach pretty closely the normal series described by Bunsen. There is some reason for believing that a certain amount of strontium is rather characteristic among the rarer bases. This is suggested not by the analyses, but by the fact that Lake Superior water contains strontium and that strontium sulphates seem to be widely distributed in some of the later formations of the region.

A notable thing is that the commonest type is the auvergnose and perhaps no rock is known which contains less silica and alkalis. Thus Iddings' statement that in general the "commonest rocks are like the average of all known rocks," certainly does not apply

[44]On September 2, 1910, after this report was written (in Science XXXII, p. 313) F. F. Grout published some excellent analyses of the Minnesota Keweenawan. The reader is earnestly requested to refer to them, finding in Grout's No. 4 a typical ophite—10% lime melaphyre, and in No. 7 an average of Keweenawan rocks, which curiously has the same percentage of copper shown by the Clark-Montreal sludge analyses. Grout also gives analyses of a number of minerals, of which the chloritic minerals are of especial interest.

[45]Compare especially with the group analyses 40 and 41 of Daly (Proc. Am. Ac. Arts and Sciences, Vol. XVL (1910) p. 224).

to the Keweenawan group. Perhaps we might connect with this another fact, that practically none of the iron and magnesia has been concentrated by differentiation into ultra basic rocks. A correlated fact is that although the analyses are all above the line (Fig. 12), I suggested as the eutectic trough for the ratio of alkalis to silica, ultra alkaline nephelitic Keweenawan rocks are almost unknown. The acmite syenite cutting the Virginia slates[46] and possibly the rocks referred to by Adams[47] are the nearest to exceptions. Occasionally an analysis may (like Bed 87 of the Eagle River section) figure out a little nepheline, but I have never recognized any, though secondary analcite occurs. Now it is suggestive that while the Keweenawan analyses come above this line which I suggest as somewhere near the eutectic line, in the commonest or auvergnose type there is little tendency to porphyritic texture. Nor is there much difference apparently in the age of the different constituents. The augite is commonly the last, yet only slight difference in composition seems to make a difference in the order of formation of the different ingredients. At any rate there is an overlap in their formation. Of the three principal ingredients, labradorite, magnetite and augite the labradorite is the first to form, the augite the last in the flows and smaller dikes, while in deeper intrusives where mineralizers had a part to play the order becomes very obscure. We may connect this, as I mention later, with the retention or loss of some mineralizer which like water has a strong tendency to keep silica in solution. But while the Keweenawan family magma seems to stand on the sodic side of the eutectic line or valley, it can not be far from it, since we do not find any ultra alkaline rocks nor is the total proportion of alkaline or acid rocks at all great compared with the volume of the average auvergnose. The Keweenawan family magma may then be characterized as anchi-eutectic, using Vogt's term, but slightly more sodic than the eutectic and super-heated. While it hardly seems wise to go into extensive comparison of similar rocks which are wide spread, yet it does seem worth while to call attention to the fact, as others have done before, that the Post-Huronian intrusives which have played such a part in the mineralization around Cobalt and Sudbury in Canada, not only seem to be of the same age as the Keweenawan but of the same general chemical type (as may be seen by comparing a page of analyses of them from Gowganda which I owe to Mr. Bowen and from the Sudbury regions which is taken from Coleman and Walker's papers.[48]

[46]Report for 1908, p. 394. Also Winchell, M. H. Proc. L. S., M. J.
[47]Journal of Geology, VIII, (1900) p. 322.
[48]Omitted. See Bowen's paper, Journal of Canadian Mining Institute, 1909, p. 517. See also R. E. Hore, J. G. 1910, p. 274. T. L. Walker, Q. J. Geol. Soc. LIII (1897) pp. 56, and 63. A. P. Coleman, Jour. Geol. XV (1907) pp. 770-782.

The eutectic line[49] of Figure 12, it may be remembered, I suggested as perhaps one of balance between the alkalis and silica (in the presence of other bases also and probably water), for it is a well-known fact that the alkalis help to keep silica in solution. It is probably not located with great accuracy and indeed must vary with the proportions of other molecules, but the grouping of analyses, collected with no such thought by Iddings, seemed to show quite plainly that the dots representing rocks were arranged along such a line or trough especially toward the more siliceous end. Now, if the line as shown in the diagram (Fig. 12) does represent with some approach to truth the hypertectic or eutectic trough it means that a rock magma which has more silica in proportion to its alkalis than those represented by the points on the line would on the whole have an excess of silica. In early crystallization from such a magma solution we might expect that silica would be removed either by itself as quartz or combined with some other base than alkalis—and supposing that base to be magnesia or lime which was in excess, the silica also being in excess, the base could easily have all that it could readily hold. We should, therefore, be liable to have diopside or enstatite formed or $RSiO_3$ rather than some one of the bisilicates. As a matter of fact there does seem to be a tendency for rocks which have early crystals,—rhyocrystals,—of enstatite, hypersthene or diopside, to have analyses, points corresponding to which fall below the line. For instance I took all of Washington's[50] analyses indexed under andesite, porphyrite, and diabase, with a few of dacite, in which the author in naming the rock had prefixed enstatite, bronzite or hypersthene, and determined their position in the diagram. Out of forty-three, thirty-three fell below the line, four on the line or just above it, leaving six only as possible exceptions. Without discussing here whether these apparent exceptions are due to analytical or other errors, are due to brotocrystals, to enclosures of bronzite, or are real exceptions for magmas of peculiar composition, it is plain that on the whole this test seems favorable to the line being located approximately. It should also be expected that in such rocks with plenty of SiO_2 there should not be so much of a tendency to form $FeO\ Fe_2O_3$ as $FeO\ SiO_2$ and Fe_2O_3. This may also be true and would give them a red appearance. On the other hand, if a magnesian base existed in excess and was ready to crystallize and the silica was deficient with regard to the alkalis

[49]Or trough. If on Fig. 12 perpendicular to the paper lines to represent fusibility were erected, the surface joining the upper ends of the lines should have a valley or trough along that line.

[50]Analyses of igneous rocks, U. S. Geol. Survey Professional Paper No. 14, 1903.

the tendency then would naturally be that the base would take as little silica with it in crystallizing as it could, so that we should find olivine ($2MgO\ SiO_2$) instead of enstatite ($MgO\ SiO_3$) as the rhyocrystal formed. Now, it is characteristic of the Keweenawan rocks, so far as I know them, that the porphyritic femic rhyocrystals are almost without exception olivine, and never enstatite and very often a feldspar more alkaline than labradorite. This is entirely in harmony with the position of the Keweenawan analyses above the eutectic trough as shown in Figure 12.

§ 6. MAGMATIC CONCENTRATION.

Concentration due to changes that go on before the liquid rock has solidified is called magmatic concentration. There may be a settling of heavier, earlier formed crystals under gravity. To some such action Winchell's plagioclasytes on the one hand and therefore iron ores on the other may be due.

On the other hand, if in part of the fluid some constituent crystallizes out owing to lower temperature, less gases, or any other cause there may be a migration of the substance which has been thus excreted from other parts of the fluid. Just so in the manufacture of artificial ice some salts will be found concentrated in the residual water, others not. Two forms of this I have called wet and dry differentiation.

§ 7. WET AND DRY DIFFERENTIATION WITHIN THE FAMILY.

Along the alkali-silica trough or eutectic line above mentioned (Fig. 12) there must be a tertiary eutectic or direction of crystallization as between the femic constituents and the alkalis and silica, and that I have suggested[51] is probably near Bunsen's normal pyroxenic magma, as shown in the figures (Figs. 12 and 13), in case no mineralizer is present, while in case mineralizer is present, as micropegmatite shows, the tendency is to crystallize out nearly all the femic constituents at temperatures probably above 800°C., while the quartz and feldspar remain in solution to be deposited as pegmatite between 800° and 550° or lower yet. Rocks lying along the eutectic trough will not differentiate so readily in ratio of silica to alkalis. But if silica was dissolved, as at Pigeon Point, or if water were lost, there would naturally be a shift in the eutectic line or valley trough. More particularly would a loss of water make it tilt down at the less siliceous end, and shift the axis of the valley from the silica axis. We know, moreover, that a rock like A. N. Winchell's plagioclasyte may crystallize at high

[51]Tufts College Studies, Vol. III. No. 1, p. 40.

temperatures leaving a more fusible femic remnant. Thus there might readily be differentiation in the direction of the eutectic line or trough without much variation in alkali-silica ratio. Just this we seem to have in the transition rocks (SS. 17033, 17007, 17037) just under (16951) the Mount Houghton felsite, as well as in the separation of the plagioclasyte of A. N. Winchell where a lighter feldspathic part may be conceived to have risen to the top while still keeping close to the $SiO_2:Na_2O = 12:1$ ratio. But we find variations of composition in more than one direction. In the first place we find variation in composition by which the top is more sodic than the center or bottom where there is more (augite) lime in many flows, e. g., Isle Royale, SS. 15515-15523. This may, in part, be due to the crystallization at an early date of the feldspar and its rising to the top, but there are some reasons for believing that it may have taken place partly in the fluid state. The same general type of differentiation, for example, seems to connect analyses of different flows and the so-called Ashbed diabase or Tobin porphyrite type seems to stand in the same relation to the ordinary ophites as the top of a flow sometimes stands to the bottom of the same.[52] Secondly, in connection with some of the gabbros we have a group of *red rocks*—gabbro aplites or syenites—which in some respects resemble the differentiation above described, but which also differ in that the silica runs up. This does not occur in the first type of differentiation. One may very readily connect this increase of silica with the concentration of some mineralizer which like water tends to promote so markedly the solubility of silica.

Finally, we have ordinary felsites in which not only does the silica increase but also the potash. While these seem comparable in many respects with the segregation which has gone on at the center of Lawson's quartz diabase dikes, the Pigeon Point rocks, however, are, according to Bayley, partly redissolved arkoses and it is a fair question whether the potassic felsites which occur in the Keweenawan may not be possibly the products of solution of some of the Huronian feldspathic quartzites, originally full of water. Such a solution would in any case be probably selective and one would not expect the original rock and the fused rock to be exactly the same in composition.

One thing seems to be fairly well made out. The felsites as an acid rock do not occur at random on Keweenaw Point but appear to be more or less associated with two definite horizons, one of

[52]Tables 12 to 15.

them coming above the greatest and most extensive flow of the whole—the Greenstone. This felsite seems to have the focus of its distribution in the Porcupine mountains. A second group of felsites, that of Mt. Houghton, occurs much lower down, somewhere in the horizon of Conglomerates 6 and 8. Felsite outbursts seem to be associated with a temporary stoppage of volcanic activity shown by conglomerates after a big paroxysm leading to thick flows of basic lavas. A question which cannot be answered decidedly yet, is the relation between the differentiation that leads to the gabbro-aplite type of rock and that leading to the felsite. Is it possible that the gabbro aplites are only a half-way step toward the differentiation of the felsites? The relationship is certainly not serial because the soda increase is checked when we pass on toward the felsite and the potash becomes much more prominent.

§ 8. SECONDARY CHEMICAL CHANGES.

Another interesting question pertains to the metamorphosis or change of the rocks after consolidation. No sharp line can be drawn here between the final consolidation and a work of change which at once begins. Judging by all we know the lava will be a solid rock at something not far below 900°C. and the quartz will not crystallize above 800°C., and most of the quartz of the felsites and quartz diabases was probably formed between 800°C. and 550°C., some possibly below 550°C. Many of the zeolites were formed at high temperatures. The radial coatings of chalcedony and chlorite which line interstices in some cases, especially in what I have called the doleritic texture, seem not to have replaced any other mineral, but to be deposited from the hot waters or gases which occupied the last interstices when the rock cooled off. An ordinary lava allowed to cool and crystallize thoroughly has the same porous or miarolitic texture that a mass of loaf sugar does, and this miarolitic texture or primary porosity gives opportunity for a range of reactions which may be called pneumatolytic. The presence of chlorite is particularly universal in our Michigan melaphyres. It will ordinarily be counted as secondary and yet we know very little regarding the real meaning of the chlorite—when it was formed and to what conditions its occurrence points. It may be pneumatolytic. I say "know" because though I make certain inferences and suggestions as to its probable role yet we cannot consider them as proven until the chlorite itself has been produced under them. It is of the more importance to us who are

interested in the origin of copper because the chlorite is very intimately associated with the copper, and the copper often replaces it.

A curious feature is that the mine waters contain practically no magnesium whatever and one is reminded of some experiments by T. Sterry Hunt[53] in which he found a very strong tendency in *hot water* for calcium chloride to replace the magnesium chloride. He also found silicate of magnesium deposited.

§ 9. HYDRATION YIELDING NATIVE COPPER.

In my paper before the Lake Superior Mining Institute[54] I suggested that the formation of native copper could be chemically conceived without going outside the formation by assuming a small hydration of the melaphyre and a change of ferric to ferrous iron, and, as a printer not used to such formulae got them confused, I wish to repeat them here. I assumed for the composition of the melaphyre a formula as follows:

$$CaO\ MgO\ (aNaO,\ bFeO,\ cCuO)\ (dFe_2O_3,\ eAl_2O_3)\ 4SiO_2$$

and, as I said, $(a+b+c)=1$, and

$$(d+e)=1 \text{ often nearly,}$$

if, now, we assume the melaphyre changed into chlorite, epidote, quartz, copper and water glass we have the following result:

[53] Chemical and Geological Essays, pp. 122, 138, 151.

[54] Vol. XII, pp. 85-86; Vol. XIII, p. 148. The discussion in U. S. G. S. Monograph 52 with new analyses, pp. 580-592, is especially valuable. The argument that the waters were hot is strong. I think that there is indication that they were also heating up, that is, circulating down into a mass of still hot rock. The analyses of vein and wall rock at the Winona Mine (p. 583) seem to check very well with the formation of epidote assumed in this section.

HYDRATION YIELDING NATIVE COPPER.

Molecule	4 SiO_2	d Al_2O_3	e Fe_2O_3	b Fe O	c CuO	CaO	MgO	a (Na_2O K_2O)	Add H O_2
All Al_2O_3 as Amesite $H_4Mg_2Al_2SiO_9$	d SiO	d Al_2O_3					2d MgO		2d
Balance Mg as Serpentine $H_2Mg_3Si_2O_9$	2-3(1−2d) SiO_2						3-3(1 − 2d) Mgo		2-3(1 − 2d)
All iron as Epidote $H_2Ca_4Fe_6Si_6O_{26}$	6-6(2e + b)		3-6(2e + b) Fe^2O_3	1—2 bO_4	$\frac{1\text{-}2\ bCu}{=0}$	$\frac{4\text{-}6(2e+b)}{=0}$			1-6(2e + 6)
Na_2O 4SiO_2 in solution Water glass	4a		$\left\{\begin{matrix} 3eO + 9\text{-}6bO \\ = 1 - \frac{1}{2} bO \end{matrix}\right\}$		if c = 1-2 b	if 2e + b = 6-4 = 1 − 1-2 = 1.5		$\frac{a}{=0}$	

Quartz = 4 − 2-3 − d + 4-3d − 6-6(2e + b) − 4a = 2− 1-3 + 1-3d − 1 − 1-2 − 4a = 1.83 − 4a + 1-3d. This calculation requires that 2d < 1, i. e., that MgO is 2 x Al_2O_3 which is *not* generally the case, but we are assuming the alteration of only that part of the melaphyre required to reduce the copper, which will therefore be the more magnesian part.

To obtain so simple a result we must also assume that the ferrous iron and copper are so related that the ferrous iron is just able to take all the oxygen from the copper, that is that—

$$b=2c$$

We must also assume that there is enough lime for the epidote and no more, that is, that

$$4(2e+b)/6=1$$

From these equations we have with those empirically assumed in the Lake Superior paper

$$(a+b+c)=1$$
$$d+e=1$$

the following results dependent on the amount of copper.

$$a=1-3c$$
$$b=2c$$
$$d=.25+c$$
$$e=.75-c$$

Finally, if we assume in addition that no quartz is removed except that in the water glass we have an additional equation to determine c. This assumption simplifies the calculations, is made probable by the results of analyses of the Calumet and Hecla boulder, and *does not affect the conclusions.*

$$\text{Quartz}=0=4-d-2/3(1-2d)-(2e+b)-4a$$
$$=1.83-4a+1/3d=-2.083+12-1/3c$$
$$c=75/444=.169$$

Assuming, then, that c=0.169 we may obtain the following values:

$$c=.169$$
$$b=.338$$
$$a=.493$$
$$e=.581$$
$$d=.419$$

The ideal melaphyre in this case will have the molecular proportions of Column 1 below. Comparing it (reducing the silica to the same amount Column 2) with the molecules of an ophite (Table XV, Analysis 5, Column 3) we notice that the alumina is low, and we can make the melaphyre more like our Keweenawan melaphyres and at the same time the epidote more like a normal epidote by supposing that e instead of being Fe_2O_3 was largely Al_2O_3. Transferring then .419 molecules from femic iron to alumina we get the results of Column 4. Column 5 is 4 made comparable with Columns 2 and 3 by making the silica the same. Multiplying by the molecular weights we get the percentages (nearly) given in Column 6. In this column the water is supposed to have been added to the 97.2 melaphyre, but may have been present originally in interstices. If for instance, the specific weight of the fresh lava was 2.88 (2.88 tons to the cubic meter) then 97.2 tons of it could occupy about 33.7 cubic meters, and the total space occupied would be 37.8 cubic meters of which space 11 per cent would be occupied by water. The original specific gravity of the whole would be 101.3/37.8=2.68.

While this process may account for small specks of native copper found in the doleritic interstices, I do not suppose that the great masses have been collected so simply.

IDEAL AND REAL MELAPHYRES TO ILLUSTRATE THE HYDRATION AND CONCENTRATION OF COPPER.

	1	2	3	4	5	6	7
SiO_2	4.000	.753	.753	4.000	.753	45.2	241.6
Al_2O_3	.419	.079	.155	.838	.158	16.1	85.9
Fe_2O_3	.581	.109	.120	.162	.030	4.9	25.9
FeO	.338	.064	.061	.338	.064	4.6	24.3
MgO	1.000	.188	.179	1.000	.188	7.5	40.4
CaO	1.000	.188	.185	1.000	.188	10.6	56.1
Na_2O } K_2O	.493	.093	.042	.493	.093	5.8	30.6
H_2O+				Added		Added.	
H_2O-				1.196	.226	4.1	21.6
TiO_2							
P_2O_5							
CO_2							
S							
SO_3							
CuO	.169	.031	.0002	.169	.031	2.5	13.5
	8.000	1.505	1.495	9.196	1.731	101.3	539.9

1. Ideal melaphyre after formula above, using numerical values found for a, b, c, d and e.
2. Same as No. 1 divided by 4/.753.

3. Real melaphyre for comparison.
4. Ideal melaphyre with adjusted alumina.
5. No. 4 divided by 4/.753.
6. Ideal cupriferous melaphyre in per cents.
7. No. 4 multiplied by molecular weights.

§10. ALTERATION OF CALUMET AND HECLA BOULDER.

In his chapter on the paragensis of the minerals associated with copper[55] Pumpelly gives a full account of "replacement of porphyry matrix by chlorite and copper" as follows:

"Among the pebbles in the Calumet conglomerate there is a variety of quartz porphyry, with a brown, compact, almost jaspery matrix, which only glazes slightly before the blowpipe. In this paste there are numerous grains of dark quartz 1/20 to 1/4 inch in diameter, and often more frequent crystals of flesh red feldspar, apparently orthoclase,—1/10 to 7/10 inch in length.

"It not rarely happens, that in these flesh red crystals there appear dirty green portions exhibiting the twin-striation of a triclinic variety. The feldspar is hard and brilliant, but is nevertheless no longer intact; under the glass the crystals appear cavernous, 10 per cent or more of the substance being gone. This is the character of this porphyry in the freshest pebbles.

"I have before me a pebble 4 inches in diameter, broken through the middle. It was the same variety of porphyry I have just described—the same brown matrix, with the same grains of quartz, and the same large crystals of orthoclase, often enclosing crystals of triclinic feldspar. But this pebble carries on its face the history of an extreme change. In the interior, where it is freshest, the matrix, still of the same brown color, has become so soft as to be easily scratched with the point of a needle. The quartz grains are highly fissured, and the surfaces of the fissures are covered with a soft, light-green magnesian mineral. The feldspar, although it still resists the point of the steel needle, has generally lost its glance, and has an almost earthy fracture; it is lighter colored, and tends to spotted dirty-red and white. In places, specks of chlorite are visible in the holes in the altered feldspar, and the cleavage planes often glisten with flakes of copper. As we go farther from the middle of the specimen toward the original surface of the pebble, the matrix becomes much softer, though still with brown color and brown streak, and then changes to a soft, green chloritic mineral, which whitens before the blowpipe, and fuses on the edges to a gray glass. A little farther from the center there is no longer a

[55]Vol. I, pt. II, Chapter III, p. 37.

trace of the porphyry matrix, it is altered wholly to chlorite. The feldspar crystals are somewhat more altered here than they are in the middle of the pebble, but the quartz grains seem to have been in part replaced by chlorite. The change to chlorite is accompanied throughout by the presence of a large amount of copper. While in the interior of the pebble, the flakes of copper are confined to the cleavage planes of the feldspar, and the porphyry matrix exhibits scarcely a trace of the metal, the chlorite which has replaced the matrix contains in different parts of the specimen from 10 to 60 per cent, by weight, of copper.

"In another pebble of the same porphyry, not only is the original matrix gone, but the usurping chlorite has been almost, if not wholly, replaced by copper; and we have as the remarkable result a quartz porphyry whose crystals of feldspar and grains of quartz lie in a matrix of metallic copper. There is still a very small amount of chlorite present, but it seems to have come from the change of the feldspar crystals and quartz grains.

"In other pebbles of the same quartz porphyry, containing, perhaps, less quartz, the alteration seems to have taken a somewhat different direction, or at least the result before us is different. In the interior of the pebble, the matrix is of a darker and dirtier brown than in the previous cases, which may be due to the presence of manganese in the alteration product. Going from the middle, the brown color changes rather abruptly to a dirty greenish-grey; the material also becomes softer, but it is earthy, with an earthy odor, and gritty to the touch. The change seems here to be in the direction of kaolinization.

"The entire pebble is permeated with minute shining threads and plates of carbonate of lime. The lighter colored portion contains considerable copper, while nearer the surface of the pebble it is largely replaced by that metal. Pebbles showing the various alterations described above are by no means rare. Many of them, from 1 inch to 1 foot in diameter, are found every day."

In Economic Geology, Volume IV, Number 2, pages 158-173, I gave a description and analysis of a boulder of the Calumet and Hecla conglomerate which was being replaced by copper. It was originally some sort of a porphyry. Oligoclase phenocrysts remain embedded in it as were noted by Pumpelly.

Pumpelly's observations, minute for the time, were not, however, supplemented by chemical analyses. Two analyses of these boulders are presented in Table XVII. Side by side are placed analyses of country rocks comparatively little affected by alteration. Just

what the original composition of one of these altered pebbles was is a question which one must be cautious in answering, but the general trend of change is unmistakable. Take, for instance, the partial analysis of a boulder by G. H. Heath, chemist of the C. & H. Mining Co. This was a "bluish grey, greasy deposit like talc found inside a boulder," the outer shell of which was turned to copper. The partial analysis was:

Silica, SiO_2	36.75	= .612 molecule.
Alumina and Iron oxide { or as FeO)	24.57	= .294
(Fe_2O_3, Al_2O_3	27.34	
Magnesia, MgO	23.24	= .581
Loss on ignition H_2O; CO_2	11.07	= .616
Difference $Na_2O + K_2O$?	1.6	= .026?
	100.00	

This evidently corresponds closely to a formula $2H_2O$, $2MgO$, FeO, $2SiO_2$ closely allied to that of serpentine. Serpentines are often derived from peridoites. Thereare, to be sure, peridotites known in the Lake Superior region, but it is most probable that the original rock was not more basic than an ophite, perhaps much more silicious.

Fortunately I was able, through the kindness of J. L. Nankervis, the commissioner of mineral statistics, to obtain another boulder of the kind in which enough of the texture was left and in particular large porphyritic crystals of oligoclase to make one reasonably sure that we are dealing with a porphyrite not so femic (rich in iron, magnesia, etc.) as the ophite but in composition between analyses 1 and 2 of Table XVII.

These peculiar boulders, yet after all at one time fairly common, which were so largely changed may have been somewhat exceptional in composition to begin with, but it is very probable, I think, that often they had originally over 60 per cent SiO_2.

DESCRIPTION OF BOULDER 20600.

This pebble or boulder (20600) as may be noted, is surrounded by a shell of copper considerably stained with carbonate, probably of recent origin. The interior next the outside is decomposed greyish-green or blanched. The main mass is mixed greenish and dark maroon, and shiny and soft. This soft (H=1) matter is the material analyzed. In it are embedded white Karlsbad-albite twins of andesite or oligoclase, one of which dug out shows P. (001), y. (201), M. (010) and the prism? (110).

While obscured with enclosures so that the refraction is not easy

to determine, for one crystal it appears to be near and a little above 1.545. In another case it is distinctly near 1.536. The extinction angle on P against M is 3°—3°, in another case 7°—7° and generally small (in one case in that zone 10—15) ? (18°—18°).

The boulder tested by Heath had a very similar ground mass. Both the albite and Karlsbad twinning are plainly visible with the pocket lens. No quartz or orthoclase phenocrysts were noticed.

This kind of alteration attacking the ground mass is not, as Pumpelly says, uncommon. Capt. Joseph Pollard, of the Calumet and Hecla mine, has quite a collection of Karlsbad twins, picked out of the soft rock, that show the crystal form nicely. They are sometimes partly replaced by copper, and are sometimes an inch or more in size. Very suggestive also is a boulder in his collection which is a mere hollow shell, lined with red feldspar (orthoclase?) and specular iron ore (hematite). Another pebble which seems to have been originally calcite, and has a calcite core, is now largely replaced by specular ore (hematite) with a little copper.

Red felsite pebbles often have blanched borders.

From Heath's and Wilson's analyses (Table XVII) of boulders and these of the slime it is clear that water has been added. Either iron has increased or there is a greater loss of other constituents than is at all likely. Alumina is probably nearly constant,—appears to be so both in the slime analysis and in 20600. Magnesia certainly is no less and in Heath's boulder much more. Lime has probably increased. If the alumina is constant, the silica has been removed. It may be noted, too, that if we suppose Sp. 17033 to be the original of Sp. 20600 the amount of silica removed is in molecules about four times that of the alkalis. If we compare the fresh felsite with the conglomerate slime, it also seems likely that much more silica than alkalis is removed. We may say, then, roughly, that iron and water have been added and water glass abstracted. It may also be noted that whereas in 17039 the rate of alkalis to silica is more than 1:12, in the boulder it is in the proportion .043:.523. Possibly alkalis in excess of the eutectic are more easily removed.

A further thing to remark is that it is doubtful if there is any marked change from ferrous to ferric iron. Water glass removed ($Na_2Si_4O_9$) and serpentine introduced ($H_4Mg_3Si_2O_9$) have the same amount of oxygen. There is, however, an uncertainty in comparing a specimen from a deep mine with specimens exposed in outcrops and necessarily oxidized. It seems then quite safe to assert that the deposition of copper in the Calumet and Hecla conglomer-

ate was one feature of a change which included also the removal of water glass and enrichment with water, magnesia and iron.

§ 11. KAOLINIZATION OF KEWEENAWAN DIKES.

An alteration in some respects similar in that water is absorbed and sodium silicate removed, but in some other respects quite different, is that of the kaolinization of the diabase dikes, evidently belonging to the Keweenawan, which is found near the iron ore bodies. These have been studied by Van Hise and Patton. Illustrative analyses are found in Table XVIII. Figure 15 gives the graphical results. In this figure the proportions of each ingredient are laid off along a horizontal line, but the length of the whole line is shortened in such a ratio that the length assigned to alumina appears constant. If the alumina really is constant, then Figure 15 gives the actual weights of each constituent remaining in an undisturbed volume of rock. Suppose the original specific gravity was 2.9, then in 13456 there was originally 100 tons of which originally 47.99 were silica. In the Aurora dike in a similar space there would be less than 19 tons of silica or 44 tons in all, more than half the dike having been removed.

A noteworthy fact is that the components are not removed at the same time in the same proportions. It appears probable that the rock is early hydrated up to a constant ratio with the alumina, that the soda and potash and the magnesia go first, the lime follows close after, the titanium oxide and silica persist. The ferrous iron either goes or is turned into ferric oxide. Later leaching removes the silica without changing the ratio of water to alumina after it reaches the proportion $2H_2O:1Al_2O_3$,—a rather noteworthy fact.

§ 12. CONCENTRATION IN SEDIMENTATION.

Another form of concentration is brought out by comparing the composition of the Keweenawan igneous rocks and the sediment which may have been derived from them.

Not many analyses have been made of the sedimentary rocks. One very obvious reason for not analyzing the conglomerates is that they vary so and the pebbles are so large that one would have to take a large sample in order to get any idea of what the average composition is. The analysis of crushed Calumet and Hecla conglomerate (1 of Table XIX) is much more basic than one would have thought. We have gathered the analyses given in Table XVII which will serve to give us some idea of the character of the sedimentary rocks and the kind of change they have undergone. No.

4 is a rock from "Siskowit Point" on Isle Royale.[56] This is from a series of dark maroon beds dipping at a high angle toward the lake. They are in all respects like the Freda sandstones. Comparing them with the basic igneous rocks we see the greater predominance of ferric iron. Comparing them with the felsites we see that there is also a greater amount of iron and of bases generally except soda and potash which must have been removed and deposited elsewhere. If we suppose these rocks not to have been derived from the felsites but from more basic rocks where the soda exceeds the potash then we must imagine at any rate a considerable addition of quartz and removal of lime. Rocks which are, however, much more likely from their looks and appearance to have been derived from the basic rocks are the so-called Nonesuch shales.[57] The analysis was of a dark grey, almost black rock which might easily be supposed to have been a bituminous rock, but is not. The dark color is due apparently to chlorite and iron oxide and some beds of the Nonesuch shale show minute scales of iron ores, etc., lying upon them and giving the bedding planes an appearance like the black sands of our present beaches.[58] The rock is also higher in alumina which is suggestive of chlorite. The alumina is just about the same as in one of the melaphyres but the silica is as much again and the iron oxides and other bases lower. The proportion of soda to potash is very similar to that which we find in the melaphyre,—large for a sedimentary. The lime is largely removed. We have here, then, a rock composed partly of quartz (petrographic examination shows ordinary quartz sand) and partly of a decomposed melaphyre in which the bases, but especially the lime, falls much short. Another analysis of Keweenawan sandstone is given by Sweet.[59] This rock lies between the Nonesuch shale and (Siskowit Point) Point Houghton rock in composition.

If we take the Calumet and Hecla slime, the Nonesuch shales, the Freda sandstone and Jacobsville sandstone we find a series fairly consecutive as to silica percentage, and as to ratio of potash to soda. The chloritic character of the Nonesuch is shown by an extra amount of alumina and magnesia. The soda also diminishes steadily.

The only way to get a fair idea of a rock like the Calumet and Hecla conglomerate or any other coarse conglomerate is to analyze

[56]Point Houghton, see Vol. VI, also Bull. 8, Minn. Sur. XXXIII, Ser. No. 165, Geol. Sur. No. 555, J. A. Dodge, analyst.
[57]Analysis 2 of Table XIX, Core at 500 feet of White Pine Exploration, d. 34.
[58]The palladium also suggests this.
[59]Geology of Wisconsin, Vol. III, p. 350.

a very large sample. The analysis of slime overflows from the trough classifiers between stamp-heads and jigs taken September, 1906, which I owe to Mr. J. B. Cooper, Superintendent of the Calumet Smelters[60] is the best representation I can give, though it contains not as much of the felsite material as I believe it should to truly represent the rock. A comparison of it with the Osceola amygdaloid slime, however, shows pretty clearly the kind of rock to be expected with any given per cent of silica.

Comparing the Osceola slime with the various analyses of melaphyres, we see that the water and alumina are relatively higher, but the iron and lime are not, the alkalis and soda are reduced.

Comparing the Calumet slime with felsite from which it may have been largely derived we again find water and alumina higher, silica and soda lower, lime, magnesia and iron on the whole higher, but rather irregularly distributed. In the conglomerate there is little or no sign of that characteristic sedimentary concentration which leads to a concentration of quartz. This certainly agrees with its brecciated and but little rehandled character.

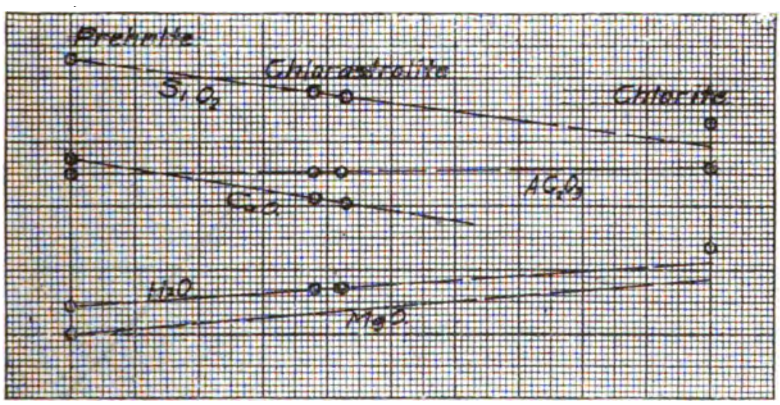

Fig. 14. Illustrates relation of prehnite, chlorastrolite and chlorite. In this diagram the percentages of silica are the abscissa, while the other elements are shown by ordinates as indicated on the diagram.

[60] "Samples taken Sept. 1906. They fairly represent the rock material, except that the slimes contain a little larger proportion of the softer portion, limy constitutents and less of hard gravel material.

"The best *average* sample of rock would be an average of all tailings for one to six months but such a sample has never been assayed completely".

	Conglomerate %.	Amygdaloid. %.
Loss on ignition	5.03	7.89
Silica	55.08	41.31
Iron oxide, Fe_2O_3	9.04	12.90
Alumina, (+tr. TiO_2)	15.41	22.46
Lime (Ca O)	7.02	11.08
Magnesium Oxide, (Mg O)	2.49	4.07
Chlorine	.18	.11
Sulphur tri-oxide (SO_3)	.04	traces.
Copper, (may be part oxide)	1.70	.14
Traces of sodium & potassium not estimated	95.99	99.96

Copper in this sample is evidently high, for an average.

§ 13. CONCENTRATION OF CHLORITIC MATERIAL.

One of the commonest changes throughout the Keweenawan rocks is the development of chlorite or green earth material. It is universal. Chlorite first appears in interstices apparently once empty, coating them in concentric agate-like bands. It also occurs after augite and later feldspar. It coats the joints. As we have seen it seems to replace even the felsitic pebbles in the conglomerate. It also replaces the prehnite as has been well described by Pumpelly and as Hawes says chlorastrolite seems to be but a half-way house between prehnite and chlorite. This is shown by Figure 14.[61] In table XVI are grouped together some analyses of chloritic material. They vary a good deal and are very inaccurate, yet there is a plain tendency toward a composition containing about 30 per cent silica, 30 per cent alumina, 30 per cent ferrous iron or magnesia and 10 per cent water ($H_4Al_2FeSi_2O_{10}$), especially if one considers the probable character of the errors due to impurities. The gangue No. 5 may be considered as made up of about 40% silica + 60 % of (31% SiO_2 33% $Al_2O_3$20% FeO 2% MgO 13% H_2O).

§ 14. CONCLUSIONS.

One will find a marked similarity in many of the processes of secondary change above given. We may tabulate them thus:

	1	2	3	4	5	6
SiO_2	decrease	decrease	decrease	decrease	increase	decrease
Al_2O_3	increase?	increase?	increase	increase	increase	constant?
Fe_2O_3	increase	increase?	increase	increase?	....	decrease
FeO	....	....	....	....	....	decrease
MgO	increase	?	increase?	increase?	....	decrease
CaO	....	....	increase	decrease	....	decrease
Na_2O	decrease				decrease	
K_2O		decrease	decrease	?		decrease
H_2O-	....	....	....	....	....	....
H_2O+	increase	increase	increase	increase	increase	increase

TABULATION OF CHANGES IN PROPORTIONS OF VARIOUS CONSTITUENTS.

The analyses upon which this table is based will be found in the other tables.

1. Calumet & Hecla boulder changed to chlorite.
2. Original rocks and Calumet & Hecla slime.
3. Ophite to Osceola slime.
4. Prehnite to chlorite.
5. Original igneous rocks to sediment.
6. Diabase dike to kaolinite.

But it is by no means necessary to infer that the change goes on

[61] See also Grout's paper in Science 1910, Vol. XXXII, p. 312, and U. S. G. S. Monog. 52, p. 582.

pari passu for all ingredients. Quite the contrary. It seems as though the water were introduced first until the ratio was in percentages about 1 per cent of H_2O to 3 per cent of Al_2O_3, or in molecules about $2H_2O$ to $1Al_2O_3$. After this there is practically no further addition of H_2O,—the farther apparent gain being due to the subtraction of other ingredients?

The alkalis and the silica seem to be removed together. If they go off as water glass (Na_2O $.4SiO_2$) the per cent proportions will be 1 per cent Na_2O to $3.885SiO_2$. The ratios obtained by comparing the diabase porphyrite 17039 with the altered Calumet boulder (59.92—31.43/10.3—0.2) or the Calumet tailing with felsite (75.67—55.08/8.74—4.01?) are fairly harmonious and if we compare the Osceola amygdaloid tailings with some of the fresh or lime melaphyres,—say the latest analysis of the Greenstone—we see that the ratio is similar within the limits of analytic error and variation in composition due to washing out the chlorite (47.69—41.31/2.44—0.04). The alkalis always escort off more than as much silica.

It is plainer from the looks than from the analyses that the ferrous iron is often, perhaps not always, largely changed to ferric iron, although that also appears in 20600. All the fresher melaphyres show large quantities of ferrous iron.

The role of the lime is least simple. Owing to the fact that before or in the process of crystallization there was a good deal of differentiation of lime it is harder to be sure what the percentage was originally and calcite may often have been introduced. In the salic rocks it seems to increase, being derived from the surrounding femic rocks. We may note the fact that the 10 to 12 per cent of lime that might have existed in a fresh lime melaphyre—an ophite—seems not to be exceeded in alteration. There are many things which I have seen,—such as the replacement of a pebble of calcite in the Calumet and Hecla conglomerate by hematite, which surrounded it,—which lead me to feel sure that the trend of the lime is toward the calcite, epidote, and calcium chloride dissolved in the mine water, so that lime also is removed from the original rock unless epidote or calcite accumulates. While the magnesia and iron really tend to form chlorite, and this alteration is conspicuous in the color change and under the microscope there is little sign of it in the analyses. The Osceola amygdaloid tailings though relatively coarse had, however, no doubt lost some chlorite in washing. I have shown above that a small absorption of water without any other great change might make a great change to chlorite, but in the alteration of the Calumet and Hecla boulder and in the change

of prehnite through chlorastrolite we must have, however, a real "metasomatic" action in which magnesia is actually introduced.

The chemistry of the mine waters and a further discussion of the chemistry of the copper deposition will be found in later chapters.

§ 15. DENSITY OBSERVATIONS.

The density of the rocks is generally given in connection with the chemical composition. Of this it is indeed a function. Yet it seems to have especial importance,—enough to warrant a brief treatment here, especially since many tests have been made of density apart from chemical analyses. Jackson's report[62] contains a large number of observations of density scattered through it and many of these are repeated in Foster and Whitney's report. They are tabulated below. In connection with the analyses which have been made from time to time tests of specific gravity have been made which are assembled in the tables.

The most extensive work, however, is that which has been done by President F. W. McNair in connection with his determination of the density of the earth by the observations about the Tamarack shaft. I have not tried to abstract this work which is not yet published but a word of explanation may be of interest and serve to draw attention to it.

Any object vibrating before a source of attraction vibrates more or less rapidly according to the strength of the attraction. This can be readily tested with a compass needle and a magnet. It is also true of a pendulum attracted by the earth. The rate of vibration of the pendulum depends upon the attractive force of the earth. The strength of magnetic attraction may be measured by the Dip Compass in the same way. Now in the case of a pendulum swinging at the bottom of a deep shaft the pendulum is no longer attracted downward by the whole mass of the earth but only that part which is still beneath it and it will accordingly vibrate slower. Comparing the rapidity of vibration of the pendulum swinging at the bottom of the shaft with that at the top, one can compare the attractive force of the spheroid beneath the pendulum,—that is to say, an earth which has a radius about a mile shorter with the attraction of the whole earth—and if we know the density of the intervening shell—that part within three or four miles around the shaft is the most important,—it becomes possible to estimate the density of the earth. In consequence President McNair had a large number of accurate sp. gr. tests made and he has kindly enabled

[62] Ex. Doc. No. 5, 31st Congress, 1849.

me to cite the figures below. It will be noticed that the mean value of the specific gravity of the trap and of the amygdaloid is very nearly the same although the amygdaloid may possibly be two per cent less and that the numerous earlier observations of specific gravity from various places are not far from the values he obtained. This shows that his values are fairly representative not merely for the neighborhood of the Tamarack shaft but the formation as a whole. It is noticeable that whereas the amydaloid was originally a very bubbly, open and glassy rock, probably having very much less density than the trap, it is now all about the same density. On the whole it is much more altered. This increase in density will be, then, entirely consistent with the reactions above suggested which seem to have actually produced condensation. It is noteworthy, too, that while the conglomerate is somewhat lighter than the traps, it is rather heavier than one would think, for its specific gravity as compared with the quartz porphyries of which it is so largely composed is several per cent greater. This may be due to the very considerable presence of epidote in the lower and calcite in the upper levels which might make a difference in the specific gravity.

The minimum value of the specific gravities approaches very closely that of kaolin. It is conceivable that through zeolites a much less specific gravity might be obtained and the fact that no such specific gravity was obtained in the three hundred and eighty-eight samples shows that none of them contained any large amount of the lighter zeolites. These results are of considerable interest in connection with the question as to the effect of secondary chemical alteration. I think it may be fairly said that there is no very marked sign of expansion by hydration (although on the whole the mean specific gravity is somewhat less than most of the basalts whose specific gravities are given by Rosenbusch) for the mean value is just about that of the Breitfirst dolerite and the maximum value of the specimens and their range compare on the whole very closely. The basaltic glasses are distinctly lighter.

The mean density is, of course, a factor which comes in in numerous other calculations and is of practical value. It may be worth remembering that 1,000 ounces of water make a cubic foot, nearly enough for most practical uses, so that by multiplying the specific gravity of a rock by 1,000 you will get the weight in ounces of a cubic foot. The average weight of the Keweenawan traps is, therefore, about 2,880 ounces or 180 pounds per cubic foot.

The following are the data that I owe to the kindness of President F. W. McNair and Prof. James Fisher, Jr., of the Michigan College of Mines. They are derived from a very elaborate series of observations made near the Tamarack shaft in connection with President McNair's determinations of gravity. It was found with regard to the deeper samples that owing to the presence of calcium chloride no definite specific gravity could be found so that the accuracy of the fourth decimal place in individual samples was nil.

Mean value of Specific Gravity of Trap (68 samples)	2.8865
Maximum value of Specific Gravity of Trap	3.0904
Minimum value of Specific Gravity of Trap	2.7623
Mean value of Specific Gravity of Amygdaloid (50 samples)	2.8454
Maximum value of Specific Gravity of Amygdaloid	3.0936
Minimum value of Specific Gravity of Amygdaloid	2.7034
Mean value of Specific Gravity of Conglomerate (10 samples)	2.7368
Maximum value of Specific Gravity of Conglomerate	2.8633
Minimum value of Specific Gravity of Conglomerate	2.6180
Mean value of Specific Gravity of Whole (388 samples)	2.8754
Maximum value of Specific Gravity of Whole (epidote?)	3.2425
Minimum value of Specific Gravity of Whole (Fluccan)	2.5427

Jackson gives in his report (p. 495) the following specific gravities:

Crystalline Black Trap from Copper Harbor	2.743
Red amygdaloid from near Porters Island near Copper Harbor	2.743
Gray amygdaloid, extremity of K. Pt	2.702
Gray amygdaloid, Eagle Harbor	2.743
Porphyritic trap with crystals of red feldspar from Copper Rock Co. location, south side of Keweenaw Pt. Possibly the Kearsarge foot or diabase porphyrite	2.751
Lac la belle Red porphyry (cf. F. W. Wright, may be Mt. Houghton felsite, but more likely the gabbro aplite) subcrystalline	2.631
Amygdaloid trap containing about 8% copper	3.925
Resultant for Am. trap without copper. (A. C. L. Comp.)	2.92 to 2.94
Another sample	3.112
Compact red jasper (felsite) of Mt. Houghton	2.572
Granular epidote containing 26.1% Metallic Copper from Isle Royale	4.854
Resultant for epidote without copper, A. C. L.	4.20
There must be leucoxene or iron oxides mixed with the epidote, the specific gravity of which is not over 3.49.	
Copper native from the Copper Falls Mine	8.9308
Copper native from Boston and Pittsburg Co. (Cliff)	8.89
	8.93
Silver	10.496
Silver, not perfectly pure from No. 2	10.288
No. 3	10.188
No. 4	10.146

Macfarlane in his report made extensive tests of specific gravities:[63]

For Melaphyre at the Quincy mine he gives specfic gravity........	2.83
Atlantic mine amygdaloid................................	2.78
Trap under Albany and Boston	2.81
Trap under Albany and Boston	2.89

There are also a large number of observations of Michipicoten rocks running as low as 2.477, but the "black felsite" usually runs about 2.573 to 2.678; melaphyre glasses are usually 2.71 to 2.79. The greatest density he gives is 2.92, but generally the melaphyres run a little under, say 2.87 quite as McNair finds them.

Marvine in Volume VI, Part 2, pp. 97, 99, 100 (Bed 91, sp. gr. 2.95), 118 (Bed 1, sp. gr. 2.94); 121 (Bed 17, sp. gr. 2.56); 123 (Bed 22, sp. gr. 2.72 and 2.77); 123 (Bed 38, sp. gr. 2.79); 125 (Bed 45, sp. gr. 2.91); 129 (Bed 65, sp. gr. 2.70-2.66); 130 (Bed 66, sp. gr. 2.98 in melaphyre, in amygdaloid 2.84, (Bed 67, sp. gr. in melaphyre 2.88); 131 (Bed 82, sp. gr. in melaphyre 2.87), 133 (Bed 90, sp. gr. in melaphyre 2.89) (Bed 91, sp. gr. 2.89-3.01-2.95) (Bed 92, sp. gr. 2.89); 134 (Bed 94, sp. gr. 2.94) (Bed 96, sp. gr. 2.90); 135 (Bed 104, sp. gr. 2.91) (Bed 107, sp. gr. 3.03), 136 (Bed 108, sp. gr. 2.95-2.92) gives a number of specific gravities on the Eagle River section, especially of the Greenstone. The specific gravity of the rock he made 3.02, feldspar 2.73, augite,—probably an ophitic impure grain? 3.39. At the margin (Bed 91) he found specific gravity 2.92 at bottom, perhaps more glassy, 2.95 at top. Other observations are given both of melaphyres, amygdaloids and sandstones. The latter (No. 17, 2.56, No. 26, 2.68, No. 63, 2.61) run distinctly lighter. He notes No. 65 as (2.98) extra heavy owing to "the copper and iron present." No. 67 was 2.88. The average of ten observations on the Greenstone beds 90-108 is 2.939.

I do not find that Irving, Wadsworth, or Rominger paid much attention to specific gravities, as microscropic methods of determining the rocks were superseding them.

While the more augitic flows, the ophites, one might expect to find heavier and darker than the porphyrites with more soda, the difference is completely disguised by other factors of primary or secondary variation such as the relative abundance of epidote and copper, or chlorite and calcite and zeolites among minerals, and the amount of primary olivine and iron oxides. The felsites are, of course, distinctly lighter, as well as the sandstones.

§ 16. TABLES OF ANALYSES AND NOTES.

TABLE I.

Lighthouse Point dike. This with the analysis of Tables II-VIII are perhaps of the original Keweenawan magma and are of intrusives showing but slight differentiation, a little accumulation of CaO at center. They were analyzed June 30, 1903, under direction of E. D. Campbell, by E. E. Ware at Ann Arbor. (See Jour-

[63]Geology of Canada, 1866, pp. 142, 143, 147, 154, 160.

nal of Geology, XII (1904) p. 89). They show very marked resemblance to Nos. 1 and 2, perhaps from a "Logan sill" of Table II.

	1	1a	3	3a	6	6a	8	8a
SiO_2	46.98	.783	47.67	.794	47.25	.787	47.10	.785
Al_2O_3	17.85	.174	17.55	.171	18.00	.176	17.47	.170
Fe_2O_3	3.13	.020	2.51	.015	2.21	.014	2.66	.016
FeO	10.36	.143	12.69	.176	12.42	.172	12.93	.179
MgO	7.16	.178	5.65	.141	6.35	.159	6.88	.172
CaO	8.47	.151	10.75	.192	11.45	.204	10.27	.183
Na_2O	2.04	.032	2.21	.035	1.96	.030	1.91	.031
K_2O	.60	.006	.65	.006	.66	.006	.59	.005
H_2O-	1.45	.081	.05	.002	....	....	....	....
H_2O+	3.02	.167	2.02	.112	....	....	....	....
TiO_2	....	....	....	....	....	....	....	....
P_2O_5	.143	.001	.169	.001	.158	.001	.161	.001
CO_2	....	....	....	....	....	....	....	....
S	.097	.002	.183	.004	.086	.002	.111	.003
SO_3	....	....	....	....	....	....	....	....
MnO	.26	.003	.19	.002	.18	.002	.15	.001
Cl	.07	.001	.05	.001	.02	.001	.09	.002
	101.80	1.742	102.422	1.652	100.744	1.554	109.522	1.547
Alkali m. / Silica m.	....	.048	....	.053	....	.047	....	.0472
Pore space to solid space	....	.0473	....	.0012	....	.0032	....	.0018
Sp. Gr.[1]	....	2.83	....	3.02	....	3.01	....	3.02

[1]Taken in gasolene.

1. Contact.
1a. Molecular proportions.
3. .616 mm from margin.
3a. Molecular proportions.
6. 4.115 mm from margin.
6a. Molecular proportions.
8. 7.6 mm from margin.
8a. Molecular proportions.

TABLE II.

Analyses by A. N. Winchell, of Minnesota Keweenawan rocks. Nos. 1 and 2 are of a sill very much like the Lighthouse Point dike, with possibly a slight settling of iron to the bottom, lower northern side. Or is the iron absorbed? These are from his thesis ("Study of the Gabbroid Rocks of Minnesota") of intrusives of probably Keweenawan age, except perhaps No. 3. They are given on page 149 of the French edition of the thesis and also in the American Geologist, Dec., 1900, pp. 373-376 (and p. 262).

	1	1a	2	2a	3	3a	4	5	5a
SiO_2..	47.70	.795	47.90	.798	49.78	.830	53.38	35.81	.596
Al_2O_3	19.04	.186	19.92	.195	29.37	.288	29.70	14.32	.140
Fe_2O_3	.87	.005	4.92	.030	.34	.002	.21	7.38	.046
FeO..	8.84	.123	9.78	.137	.60	.008	....	15.25	.211
MgO..	8.65	.216	4.55	.113	1.01	.025	tr.	10.49	.262
CaO..	8.96	.159	8.56	.152	11.86	.211	11.90	17.23	.307
Na_2O.	2.53	.041	2.75	.044	4.39	.071	4.30	2.06	.033
K_2O..	.53	.005	.56	.005	.46	.005	.56	.37	.003
H_2O-									.291
H_2O+	1.38	.078	.76	.043	1.76	.097	.37	5.23	
TiO_2..	1.80	.022	.57	.006	....	....	....	2.30	.028
P_2O_5.	n. d.	....	....	....	....	....	....	....	....
CO_2...	....	....	....	....	....	....	....	....	....
S.....	....	....	....	....	....	....	....	....	....
SO_3...	....	....	....	....	....	....	....	....	....
MnO..	tr.	....	tr.	....	.08	.001	....	.18	.002
Ba.SrO	.00	....	....	....	....	....	....	....	....
	100.30	1.629	100.27	1.523	99.80	1.538	100.42	100.62	1.919
Al. m. / Sil. m	....				2.676		2.701		
Sp. gr.		.058	....	.061		.092		....	.060

1. Birch Lake gabbro.
1a. Molecular proportions.
2. Logan sill, Birch Lake, east side.
2a. Molecular proportions.
3. Carlton Peak "plagioclasyte."
3a. Molecular proportions.
4. Plagioclase of 3, (p. 262).
5. Troctolyte near Duluth.
5a. Molecular proportions.

Table III.

Duluth gabbro analyses to be compared with the Ashbed magma, Table XII. It has large (3mm.) labradorite phenocrysts, rhocrystals, arranged in flow lines, and has numerous ramifying aplitic red veins. Cf. the Mt. Bohemia rocks. (Tables IX and X). This differs from the Gowganda (Canada) diabase of Bowen in having more iron and less magnesia and lime. The Sudbury norite has as much iron, but a lower alkali: silica ratio.

	1	1a	2	2a	3	3a	4
SiO_2	52.48	.875	49.15	.819	45.65	.760	46.29
Al_2O_3	15.47	.152	21.90	.215	15.20	.149	18.20
Fe_2O_3	5.14	.032	6.60	.041	6.71	.042	4.98
FeO	9.25	.128	4.54	.063	13.81	.192	5.52
MgO	2.55	.063	3.03	.076	2.95	.074	8.24
CaO	7.27	.130	8.22	.146	6.33	.113	8.86
Na_2O	3.26	.052	3.83	.062	3.09	.050	3.30
K_2O	1.75	.018	1.61	.017	1.05	.011	.76
H_2O-							
H_2O+	1.24	.068	1.92	.107	2.29	.127	3.42
TiO_2	1.26	.014	.18	.002	1.66	.020	....
P_2O_5	.29	.001	.33	.002	.25	.001	....
CO_2	....	....		....	....	....	....
S	....	....	Cu.p.n.d	....	....	....	....
SO_3	....	....	n. d.	....	....	....	....
MnO	.51	.007	n. d.	....	.71	.010	....
	100.47	1.540	101.31	1.550	100.70	1.549	....
Alkali m.							
Silica m.	....	.081	....	.0965	....	.080	....

1. From A. N. Winchell, p. 293, No. 1797. No appreciable BaO or SrO. Sp. Gr. 2.81 to 2.84.

1a. Molecular proportions.

2. Same cited from A. Streng, Neues Jahrbuch, 1877, p. 117. MnO and Fl not determined. TiO_2 and P_2O_5 determined separately. Original total 100.80. Chalcopyrite present.

2a. Molecular proportions.

3. Hornblendic variety, of No. 1 richer in iron.

3a. Molecular proportions.

4. Average of analyses of 15515 (top) and 15523 (bottom) of Ashbed diabase, Isle Royale hole 10., 338-415 for comparison. This has more MgO and contained olivine.

Table IV.

Bunsen's normal trachytic and normal pyroxenic analyses for comparison. The Keweenawan magma is short in lime compared with the normal pyroxenic, but the ophites approach it closely. This may be the pyroxenic eutectic, while the normal trachyte is not far from Vogt's and Teall's micropegmatite eutectic. Nos. 1 and 3 are Bunsen's ideal normal trachytic and pyroxenic magma while Nos. 4 and 5 are actual analyses of Iceland rocks supposed to be a mixture of the two in varying proportions. These are cited from Neumayr's Erdgeschichte, Vol. I, p. 169. No. 2 is of a spherulite from a porphry, cited by Vogt after Lagorio as Nos. 22a

and 31b of his table of quartz feldspar eutectics, p. 174, Part II of "Die Silikatschmelzlösungen."

	1	1a	2	3	3a	4	4a	5	5a
SiO_2....	76.67	1.277	76.48	48.47	.807	51.75	.862	73.37	1.222
Al_2O_3..	14.23	?.128	12.06	30.16	.147?	28.31	....	16.09	....
Fe_2O_3..	....	? 013	0.95	....	.095?	....	....	....	....
FeO....									
MgO....	0.28	.007	0.39	6.89	.172	6.13	.153	1.05	.026
CaO....	1.44	.026	0.64	11.87	.211	10.65	.190	2.66	048
Na_2O...	4.18	.068	4.89	1.96	.031	2.20	.035	3 93	.063
K_2O....	3.20	.034	3.78	0.65	.006	0.96	.010	2.90	.031
H_2O—..	....	....							
H_2O+..	....	....	?0.77	....	....	....	....	....	....
TiO_2....	....	....	....	....	....	....	....	....	....
P_2O_5...	....	....	....	....	....	....	....	....	....
CO_2....	....	....	....	....	....	....	....	....	....
S.......	....	....	....	....	....	....	....	....	....
SO_3....	....	....	....	....	....	....	....	....	....
Alkali m.	....	.080	.097	....	.045	....	....	....	....
Silica m.									
	100.00	1.412	99.96	100.00	1.227	100.00	1.250	100.00	1.390

1. Normal trachytic.
1a. Molecular proportions.
2. Spherulite (quartz feldspar eutectic) El Pablon, de Itulgache Ecuador.
3. Normal pyroxenic.
3a. Molecular proportions.
4. Reygadalr Foss.
4a. Molecular proportions.
5. Klettaberge.
5a. Molecular proportions.

TABLE V.

Analyses of minerals of Keweenawan basic rocks. Nos. 1 to 3 are from United States Geological Survey Bulletin 418, p. 51. With No. 1 should be compared analyses G, I, J, K of the same bulletin, page 56, of Minnesota gabbro feldspars. With No. 3 should be compared an old analysis by Jackson (Table XIV, No. 3) and analysis 5 by Winchell. It appears that plutonic rocks crystallize under conditions in which less alumina goes into the pyroxene. Cf. r and other analyses in Idding's table of analyses of pyroxene.

	1 H	2 I	3 J	4	5	6
SiO_2		53.30	49.80	45.05	48.34	33.57
Al_2O_3		29.03	2.86	.16	2.90	
Fe_2O_3	50.29	.55	2.48	5.50	4.68	
FeO	30.70	.23	10.82	14.90	14.15	48.74
MgO		.13	15.33	15.15	11.34	17.69
CaO		11.40	16.50	10.72	15.10	
Na_2O		4.87	.51	1.27		
K_2O		.40	.12	.78		
H_2O-		.23	.33	.13	1.98	
H_2O+				4.39		
TiO	8.77	trace	1.29			
P_2O_5		trace	trace			
CO_2						
SrO		trace	none			
Li_2O		none	trace?			
MnO		none	.37	1.58		
BaO		trace	none			
	89.46	100.14	100.41	99.63	98.49	
Sp. Gr.				3.316		

1. Magnetite.
2. Labradorite Ab_{40} An_{60}.
3. Diallage.
4. Pyroxene from Pigeon Point diabase. Am. Geol., Oct., 1900, p. 203. A. N. Winchell.
5. Diallage from Pigeon Point. Am. Geol., Oct., 1900, p. 203. Riggs.
6. Olivine. Am. Geol., Oct., 1900, p. 204. A. N. Winchell.

1. Limestone Mountain.
2. Native silver gangue, p. 480.
3. Water in prehnite, p. 484.
4. Apophyllite, p. 484.
5. Apophyllite, p. 484.
6. Analcite red, p. 485.
7. Cliff vein, p. 489.
8. Wollastonite, p. 491.
9. Wollastonite, p. 491.
10. Anhydrous prehnite table spar or "Jacksonite," p. 492. See comments later.
11. Chlorastrolite, p. 493. F. & W., p. 97.
12. Chlorastrolite, p. 492. F. & W., p. 97.
13. Soils over Lake Superior sandstone, p. 497.
14. Soils over Trap.
15. Leonhardite (laumontite), p. 513.
16. Mendelhall's mine, p. 513.
17. F. & W. II, p. 88. Hydrous epidote?

Much better analyses, and very important is the work of F. F. Grout, Science, XXXII, (1910) p. 314.

TABLE VI.—*Miscellaneous old analyses from reports of Jackson*[1] *and Foster and Whitney*[2] *showing composition of various secondary numerals.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2	8.91	57.95		52.7	51.000	53.40		49.09	49.06	46.12	37.41	36.99	94.24?	81.10	55.04	$BaSO_4$ 64.1	42.6
Al_2O_3		19.00				22.40		.23	1.28	25.91	24.25	25.49	.47	2.61	22.34	SiO_2	31.2
Fe_2O_3	1.98										6.26	6.48	.92?	3.91		.04	
FeO		13.06															
MgO	+ CO_3 44.65	1.32						.14					+ CO_3 .07	.25			
CaO	+ CO_3 44.49	.05		23.35	24.944	3.00		46.38	44.87	27.03	21.68	19.90	+ CO_3 .32	.46	10.64	9.07	20.6
Na_2O						8.52				.85	4.88	3.70	++ SO_4 .06	.22			
K_2O				4.95	5.187							.40					
H_2O-		7.81											Org 2.92	8.93			
H_2O+			4.4	16.00	16.00	10.31		2.96	2.96		5.77	7.22	0.73	2.79	11.93	6.97	5.2
TiO_2																	
P_2O_5								MnO .48									
CO_2								.72	.90							Cu 14.03	
S							Cu 5.26										
SO_3							Ag .005									6.19	
CuF				1.85	1.94												
	100.03	99.19		98.85	99.071	97.63		100.00	100.00	99.91	100.25	100.18					99.6
Sp. Gr.				2.305		2.250 to 2.258						3.18					

[1] House Ex. Doc., No. 5, 31st Congress, 1st Session.
[2] Report on the Geology of the Lake Superior Land District, Pt. III, 1851. Ex. Doc. No. 5. Special session of Senate, March 1851.

TABLE VII.

Mount Houghton quartz porphyry. From L. L. Hubbard, Geol. Sur. of Mich., Vol. VI, Pt. II. This rock is reported by Jackson (p. 495) as having Sp. Gr. 2.572. The analyses were all by F. P. Burrell.

	1 J	1a	2	2a	3	3a
SiO_2	75.67	1.261	80.05	1.332	69.76	1.162
Al_2O_3	12.43	.121	9.73	.095	13.14	.128
Fe_2O_3	2.27	.014	1.72	.010	1.44	.009
FeO	0.15	.002	0.18	.002	0.66	.009
MgO	0.00	.000	0.00	.000	0.18	.004
CaO	tr.	....	0.83	.014	0.36	.006
Na_2O	2.01	.032	2.19	.035	2.52	.040
K_2O	6.73	.071	4.43	.047	11.90	.126
H_2O-	{ 0.41	.022	1.03	.057	0.42	.024
H_2O+						
TiO_2	....	....	....	....	....	....
P_2O_5	....	....	....	....	....	....
CO_2	....	....	....	....	....	....
S	....	....	....	....	....	....
SO_3	....	....	....	....	....	....
MnO	tr.	....	tr.	....	....	....
Alkali m. / Silica m.	....	.082	....	.066	....	.143
	99.67	1.521	100.16	1.589	100.38	1.499

1.[1] Hubbard, p. 28.
1a. Molecular proportions.
2. 17193 A[2] end of Mt. Houghton. Hubbard, p. 42.
2a. Molecular proportions.
3. 16951 Mt. Houghton, south (lower) side.
3a. Molecular proportions.

[1] 1 does not fuse at 900°, cakes and bleaches, has few small phenocrysts of feldspar.
[2] 17193A shows infiltered quartz.

TABLE VIII.

Transition rocks, porphyrite flows below Mount Houghton quartz porphyry. From L. L. Hubbard, F. P. Burrall, analyst. Perhaps Tables V and VI are both too high in alkalis, like Cook's analyses, as A. N. Winchell suggests (Jour. Geol., XVI (1908), p. 771). They indicate differentiation from right to left along the eutectic valley (Fig. 12) of the same kind as that from the Mount Bohemia gabbro (Table X) to gabbro aplite (Table IX) or syenite.

	1 E	1a	2 G	2a	3	3a
SiO_2	52.83	.880	51.45	.957	59.52	.991
Al_2O_3	16.30	.160	15.75	.154	15.58	.153
Fe_2O_3	9.60	.060	11.12	.069	7.24	.045
FeO	2.48	.035	1.74	.024	1.86	.027
MgO	3.98	.099	1.94	.048	2.11	.052
CaO	2.98	.053	0.12	.002	1.81	.032
Na_2O	6.54	.105	7.84	.126	6.82	.109
K_2O	2.49	.025	3.51	.037	3.48	.036
H_2O- / H_2O+	2.76	.153	1.23	.067	2.23	.123
TiO_2	....	....	....	....	....	....
P_2O_5	....	....	....	....	....	....
CO_2	....	....	....	....	....	....
S	....	....	....	....	....	....
SO_3	....	....	....	....	....	....
Alkali m. / Silica	....	.148	....	.170	....	.147
Sum	99.96	1.567	100.70	1.484	....	1.572

1. 17033 Hubbard, p. 25, diabase porphyrite, Bed E.[1]
1a. Molecular proportions.
2. 17007 Hubbard, p. 26.[2]
2a. Molecular proportions.
3. 17039[3] p. 26.
3a. Molecular proportions.

[1]Fusible about 900° C with microlitic ground mass and phenocrysts. Bed E of the Mt. Houghton felsite series.

[2]Feldspar near albite. Ct. gabbro aplites, Bed G. Separated from E by amygdaloid conglomerate, 915N., 1060 W. Sec. 20, T. 58 N., R. 28 W.

[3]Fusible about 900° C to dark brown glassy globule. 1340N., 360 W. Sec. 27, T. 58 N., R 28 W. cf. Praysville porphyry with 59.52 Si, O_2, much more porphyritic; felsite porphyrite, Hubbard, quartzless porphyry, Irving.

TABLE IX.

Intrusive red rock or gabbro aplite of Mount Bohemia. See F. E. Wright, annual report for 1908. Cf. Bowen's Gowganda, and the Cobalt (Canada) aplites,[1] the Pigeon Point rocks and other analyses cited by Daly, A. J. S., XX (1905), pp. 193-213. The specific gravity of rock such as Nos. 5 and 6 according to Jackson is 2.631. Nos. 5 and 6 are check analyses from the same rock specimen (not ground powder) by Newell Cook at Albion and L. Kirschbraum of Ann Arbor. Cook died before his work was finished and some figures are certainly wrong. Much like Bowen's Gowganda granophyre, but I suspect secondary introduction of an iron chlorite.

	5	5a	6	6a	7 Norm.	
SiO_2	64.53	1.075	62.28	1.038	Quartz	12.90
Al_2O_3	4.13	.041	17.54	.171	Orthoclase	17.78
Fe_2O_3	2.73	.017	1.55	.010	Albite	36.18
FeO	12.82	.178	5.64	.078	Anorthite	17.23
MgO	2.13	.053	1.51	.038	Corundum	.92
CaO	4.35	.078	3.44	.062	Hypersthene	11.07
Na_2O	0.24	.004	4.26	.069	Ilmenite	1.98
K_2O	3.86	.041	2.97	.032	Magnetite	2.32
H_2O-	0.20	.011				
H_2O+	2.60	.144				
TiO_2	.63	.008	.98	.013		
P_2O_5	0.41	.003				
CO_2	tr.					
S						
SO_3	0.62	.008				
MnO	0.79	.011				
	100.04	1.672	100.17	1.511		100.38
Alkali m. / Silica		.041	.098			
Sp. Gr.		2.668				

[1]Journal of the Can. Min. Inst. XII., 1909, p. 517.

5. Gabbro aplite. Cook loc. cit.
5a. Molecular proportions.
6. Gabbro aplite. K. loc. cit.
6a. Molecular proportions.
7. Norm.

TABLE X.

Mount Bohemia oligoclase gabbro and allied rocks. See annual report for 1908, p. 369.

	1	1a	2	2a
SiO_2	45.30	.755	46.01	.766
Al_2O_3	11.81	.116	16.95	.167
Fe_2O_3	9.94	.062	5.14	.032
FeO	9.31	.129	9.83	.137
MgO	8.09	.202	6.20	.155
CaO	8.05	.144	6.71	.120
Na_2O	0.93	.014	2.22	.035
K_2O	4.07	.043	1.71	.018
H_2O-	0.30	.017	....	....
H_2O+	2.70	.150	....	....
TiO_2	1.15	.014	2.48	.031
P_2O_5	0.80	.006	....	....
CO_2	1.49	.034	....	....
S	....	....	....	....
SO_3	0.72	.009	....	....
MnO	0.84	.012	....	....
	105.50	1.707	97.25	1.461
Alkali m. / Silica m.	....	.078	....	.056
Sp. Gr.	....	2.913	....	....

1. By N. Cook.
1a. Molecular proportions.
2. By L. Kirschbraum.
2a. Molecular proportions.

TABLE XI.

Mount Bohemia, ophite and contact modification of it. See report for 1908, p. 377.

	1	1a	2	2a	3	4	5	5a
SiO_2	44.91	.748	47.01	.783	45.69	45.85	45.9	.765
Al_2O_3	18.01	.176	17.80	.174	14.44	10.97?	15.15	.148
Fe_2O_3	4.50	.028	5.32	.033	6.21	4.97	5.00	.031
FeO	7.64	.106	6.59	.092	9.39	13.79	8.00	.111
MgO	7.67	.192	8.75	.219	2.19	1.61	8.00	.200
CaO	7.49	.134	5.31	.095	7.44	5.71	7.5	.134
Na_2O	1.75	.028	2.00	.032	0.96	0.91	2.00	.032
K_2O	1.33	.014	1.58	.017	6.96!	9.29?	1.5	.016
H_2O-	4.16	....	3.45	....	0.55	0.35	.45	.026
H_2O+	by diff.	....	by diff	....	2.35	2.55	2.45	.136
TiO_2	2.54	.030	2.19	.026	1.90	1.69	2.00	.024
P_2O_5	....	....	....	....	0.32	0.38	.35	.002
CO_2	....	....	....	....	tr.	....	....	....
S	....	....	....	....	....	....	....	....
SO_3	....	....	....	....	1.30	1.78	1.5	.019
MnO	....	....	....	....	0.33	0.14	.2	.003
	....	1.456	....	....	....	....	....	....
	95.84	....	96.55	1.471	100.03	99.99	100.00	....
Alkali m. / Silica m.	....	.055	....	.063	....	....	....	.063

1. Normal ophite, Sp. 2, F. E. W. 21. This seems low in CaO and SiO_2 for a normal ophite. It may be that iron and magnesia have been introduced in place.
1a. Molecular proportions.
2. Contact phase of same showing alteration. Sp. 2, F. E. W. 37. L. Kirschbraum, analyst.
2a. Molecular proportions.
3. Duplicate of No. 1. Analyzed by N. Cook.
4. Duplicate of No. 2. Analyzed by N. Cook.
5. Most probable analysis, estimated by A. C. L., from all four analyses, since there seems to be no essential difference in composition. Cf. Tables III and XII to XV.
5a. Molecular proportions.

TABLE XII.

Analyses of sodic melaphyres of "Ashbed," Tobin, or melaphyre porphyrite type.

	1	1a	2	2a	3	3a	4
SiO_2	50.07	.834	46.45	0.774	49.27	.834	50.03
Al_2O_3	12.63	.123	16.60	0.163	16.75	.150	15.38
Fe_2O_3	3.84	.024	2.72	0.017	7.78	.073	11.78
FeO	10.30	.143	7.25	0.100	4.86	.054	3.90
MgO£	5.23	.131	9.21	0.230	7.44	.090	3.60
CaO	6.55	.117	6.32	0.112	5.47	.094	5.39
Na_2O	3.53	.056	4.05	0.065	5.42	.080	5.01
K_2O	1.90	.020	1.02	0.010	0.48	.012	1.14
H_2O-	0.86	.048	loss	on ign	....	....	....
H_2O+	1.96	.109	5.01	0.278	3.72?	.150	2.73
TiO_2	2.50	.030	....	....	....	....	....
P_2O_5	0.22	.001	....	....	....	....	.33
CO_2	0.00	.000	0.40	0.009	0.92	.020	0.98
S	....	....	....	....	....	....	....
SO_3	....	....	....	....	....	....	....
MnO	0.42	....	....	....	Trace	....	....
BaO	0.02	....	....	....	....	....	....
	100.03	1.636	99.03	1.758	101.19	1.557	99.94
Alkali m. / Silica m.	.091	....	....	.098	....	.111	....

1. Bed 65[1] Eagle River.
1a. Molecular proportions.
2. 15515 Isle Royale, p. 146.[2]
2a. Molecular proportions.
3. 15537 Isle Royale, p. 215.
3a. Molecular proportions.
4. Streng's melaphyr porphyr, N. Jahrbuch, 1877, p. 48, Irving, V, p. 277. Compare the "melaphyre" (ophite) on p. 55.

[1]Journal of Geol. XVI, p. 772.
[2]Vol. VI, Part I, pp. 215, 143, 146.

TABLE XIII.

Melaphyre analyses of uncertain affinities. No. 1 (see Vol. VI, p. 215) is 16 feet from the top of a typical "Ashbed" melaphyre porphyrite. No. 2 is from the middle of a bed (Eagle River 87), the bottom of which is a lime melaphyre, just above the "Mesnard epidote" and below the Pewabic lode. Cited from Pumpelly, Proc. Am. Ac. XIII, p. 285. See also Irving. No. 3 is an old analysis of a rock which being above the Greenstone is more likely to be a sodic melaphyre.

	1	1a	2	2a	3	3a
SiO_2	46.99	.783	49.20	.820	47.97	.799
Al_2O_3	18.47	.181	16.00	.157	15.56	.152
Fe_2O_3	4.44	.027	3.03	.019	....	....
FeO	7.24	.100	7.10	.099	12.41	.172
MgO	6.03	.151	6.98	.175	8.28	.207
CaO	9.53	.169	3.44	.061	7.07	.126
Na_2O	3.37	.054	5.05	.081	6.24	.100
K_2O	0.33	.003	1.31	.014	....	....
H_2O-	3.90	.216	4.51	.250	2.46	.137
H_2O+	loss	....	....	....	....	....
TiO_2	....	....	2.26	.027	....	....
P_2O_5	....	....	....	....	....	....
CO_2	....	....	....	....	....	....
S	....	....	....	....	....	....
SO_3	....	....	....	....	....	....
MnO	trace	....	1.17	.016	....	....
	100.30	1.684	....	1.719	99.99	1.693
Alkali m. / Silica m.	....	.073	....	0.114	....	0.125
Sp. Gr.	2.901	....	....	....	....	....

1. 15533[1] Isle Royale, p. 215.
1a. Molecular proportions.
2. Eagle River Bed No. 87.
2a. Molecular proportions.
3. Rock Harbor trap, F. & W., Pt. II, p. 88.
3a. Molecular proportions.

[1]At the page cited will be found another check analysis which is from the same bed, 3 feet farther from the top. This is 16 feet from the top. It is the same bed as 15537 but has more lime.

TABLE XIV.

Analyses of the great flow known as the "Greenstone,"—typically an ophite, at any rate at the base, (see Pls. II and III) though large plagioclase rhyocrystals occasionally occur. None of the analyses are satisfactory. The Foster and Whitney (1) and Jackson analyses (3) are old and incomplete, and the recent U. S. G. S. analysis No. 2 shows no potash. The Jackson analysis (3) is supposed to be of the pyroxene only, but is probably of augite containing feldspar and magnetite. The latter was extracted before analysis. For comparison an ideal analysis of a melaphyre containing .265 per cent of copper is placed beside it.

	1	1a	1b	2	2a	3	3a	4	5
SiO_2....	50.20	.836	26.08	47.69	.795	51.28	.855	47.2	45 2
Al_2O_3..	15.43	.151	7.22	16.02	.157	17.12	.168	15.8	16.1
Fe_2O_3...	....	......	....	2.41	.015	....	....	4.00	4.9
FeO....	13.79	.192	3.06	8.70	.121	3.90	.054	7.2	4.6
MgO....	8.62	.215	3.34	8.31	.208	7.33	.170	6.8	7.5
CaO....	5.47	.097	1.56	10.54	.188	19.55	.349	18.—	10.6
Na_2O...	4.75	.076	1.22	2.44	.039	....	....	....	5.8
K_2O...	....	......	....	....	.000	....	....	....	} 4.1
H_2O—..	1.74	.097	1.55	0.44	.025	....	....	....	
H_2O+..	....	......	....	2.04	.114	....	....	....	
TiO_2...	....	......	....	1.38	.016	....	....	....	....
P_2O_5..	....	......	....	0.06	.001	....	....	....	....
CO_2....	....	......	....	....	.000	....	....	....	....
S........	....	......	....	....	.000	....	....	....	....
SO_3....	....	......	....	....	.000	....	....	....	
MnO....	....	......	....	0.26	.003	0.99	.014	0.9	CuO ·2 6
	100.00	1.664	....	100.29	1.680	100.17	1.610	99.9	101 3
Alkali m.	....	.094	....	....	.049	....	....	....	....
Silica m									

1. F. & W. Pt. II, p. 88.
1a. Molecular proportions.
1b. Oxygen of same.
2. A. N. Winchell, p. 772.
2a. Molecular proportions.
3. Pyroxene from same.
3. Pyroxene Jackson (p. 494) gives this analysis of a "pyroxene" associated with feldspar, magnetite and ilmenite on a hill in Sections 12 and 13, T. 58 N. R. 28 W. This is almost certainly from the Greenstone Range. The H. was 5.5, Sp. gr. 3.478. It may have been one of the ophitic augite patches as that would account for the alumina and alkalis. The magnetic part he separated. If we add enough FeO Fe_2O_3 to make the amount of iron

(A.) WEATHERED SURFACE OF OPHITE TAKEN AT ABOUT THE SAME TIME AS PLATE II BY W. J. PENHALLEGON.

(B.) WEATHERED SURFACE OF AMYGDALOID CONGLOMERATE AFTER FIGURE 2, PART 2 OF VOLUME VI.

generally found in the Greenstone,—say 8.3% $FeOFe_2O_3$ —the analysis will be closely that of the Greenstone except that the alkalis were not tested and the lime is extra high. Assignment of the bases to the silica indicates strongly that some alkalis were present, perhaps included with the lime in this old analysis. Compare, however, Doelter's analysis (Hintze CCCXI) of brown augite from a Cape Verde feldspar basalt. It may represent the eutectic, Fig. 13.

3a. Molecular proportions.

4. No. 3 witl. 8.3 per cent magnetite added.

5. Ideal melaphyre used in showing change to chlorite and copper repeated for comparison from p. 86.

TABLE XV.

Analyses from different analysts of lime melaphyre (ophites), different beds, but all of the commonest type of Keweenawan flow. The percentages of silica agree closely; the alumina agrees (allowing for the fact that the titanium oxide was not separated in two cases). The relative proportions of ferrous and ferric iron vary greatly. The MgO checks closely in the two most recent analyses. The lime is characteristic and always about 10 per cent and never 12 per cent. The soda and potash agree very closely in the two better analyses 1 and 5, and the titanium oxide is high.

	1	1a	2	3	3a	4	5	5a	5b
SiO_2	46.13	.769	46.25	46.32	.771	46.48	45.21	.753	49.3
Al_2O_3	19.79	.194	18.39	15.95	.156	17.71	15.85	.155	10.1
Fe_2O_3	7.24	.045	7.70	2.86	.018	? 21.17	9.55	.059	3.9
FeO	3.79	.053	3.52	8.92	.124		4.37	.061	4.0
MgO	7.27	.182	4.65	4.08	.102	tr.	7.25	.181	11.8
CaO	11.43	.203	12.19	10.28	.184	9.89	10.36	.185	12.2
Na_2O	2.55	.041	3.76	3.56	.057	by diff.	2.47	.039	2.6
K_2O	0.52	.005	1.04	1.23	.013	1.97	.31	.003	.2
H_2O-	1.83	.101	3.41	3.25	.180	2.78	.47	.026	....
H_2O+							.41	.023	
TiO_2	....	....	....	2.78	.034	....	2.14	.025	1.6
P_2O_5	....	....	....	....	....	....	.165	.001	....
CO_2	0.29	.006	1.00	....	....	....	.48	.011	....
S	....	....	....	....	....	....	.07	.002	....
SO_3	....	....	....	....	....	....	....	....	....
MnO	Trace	....	....	0.89	.013	....	.89	.013	.9
Cl	....	....	....	....	....	....	.04	.001	....
Moisture	....	....	....	....	....	....	.47	.026	....
	100.84	1.599	101.91	100.12	1.652	100.00	....	1.564	....
Alkali m / Silica m.	....	.0599	....	....	.091	....	....	:056	....

1. Ophitic streak 9 feet from base of same (77-foot) bed as 15515 and 15519, Eagle River 39-43, Sp. 15523; Sp. Gr. 2.877. See average composition of bed on Table III.
1a. Molecular proportions.
2. Same bed as No. 1 but 41 feet from base, i. e., near center, the extra lime evidently due to extra calcite. Sp. 15519.
3. Bed 87 just above Greenstone, base of bed more calcareous. Woodward for Pumpelly.
3a. Molecular proportions.
4. Canada report, 1866, p. 157 and seq., very incomplete but suggestively like the others; really, however, from the "Ashbed" group, a "green earth" from the Pewabic lode.
5. St. Mary's Mineral Land Co., Challenge exploration, Hole No. 5 drill core described below.
5a. Molecular proportions.
5b. Molecules reduced to per cent after Osann.

The table might be extended by analyses of Table XI, 15533 of Table XIII and the Sauk Rapids melaphyre of Streng (Neues Jahrbuch, 1877). Cf. also Table I, Nos. 3 to 8 and Grout's analyses in Science (loc. cit.) and Journal of Geol. 1910, p. 633 and the analyses in Monograph 52, p. 583, especially 1.

TABLE XVI.

Analyses of chloritic materials. See also analysis 4, of previous table.

	1	1a	2	3	4	5	6	6a
SiO_2	....	....	31.78	33.14	30.59	57.95	36.99	19.22
Al_2O_3	30.95	.303	15.47	13.22	26.07	19.00	25.49	13.90
Fe_2O_3	....	....	....	24.20	....	....	6.48	
FeO	32.47	.453	28.87	12.19	22.01	13.06	....	....
MgO	15.98	.399	4.37	3.49	12.36	1.32	....	
CaO	9.36	.167	9.64	1.50	1.92	.05	19.90	6.54
Na_2O	11.26	.181	....	....	....	....	3.70	
K_2O	....	....	....	....	....	....	.40	
H_2O—	....	....	9.87	12.34	7.23	7.81	7.22	6.40
H_2O	....	....	....	....	....	....	....	....
TiO_2	....	....	....	....	....	....	....	....
P_2O_5	....	....	....	....	....	....	....	....
CO_2	....	....	....	....	....	....	....	....
S	....	....	....	....	....	....	....	....
SO_3	....	....	....	....	....	....	....	....
	100.04	1.503	100.00	....	....	99.19	100.18	....

1. Soluble part (21.17%) of Greenstone after long digestion in HCl of Sp. Gr. 1.13, not pure chlorite. From Foster and Whitney.
1a. Molecular proportions.

2. Chloritic mineral computed from partial analysis, Quincy wall rock. Soluble part 43.36% of hanging of Quincy vein "mineral chlorite." "Smooth pellet" of green substance which does not cling to walls. See Macfarlane's "Geologie du Canada, 1866, p. 155.
3. Chlorite from amygdaloid of Pewabic lode, Quincy mine foot. Macfarlane, p. 158. Density of amygdaloid 2.78, compposition estimated 62% labradorite, 38% chlorite.
4. "Strigovite" from amygdule in Minnesota. Geol. Sur. 23rd report, p. 194.
5. Analysis of chloritic material with native silver, probably mixed with quartz from Jackson.
6. Chlorastrolite. A number of other analyses will be found in Dana's Mineralogy agreeing essentially with this. This may (Fig. 14) be considered as a mixture of prehnite 43.69 SiO_2, 24.78 Al_2O_3, 27.16 CaO, 4.37 H_2O with about 50% of a chlorite like analyses 3 or 4; the amounts of silica, alumina, lime and water checking closely.

6a. Oxygen ratio.

TABLE XVII.

Analyses grouped to illustrate derivation of sedimentary from igneous rocks.

	1	2	3	4	5	6	7	8	9	10
SiO_2	75.67	59.92	55.03	31.42	36.75	46.01	50.20	41.31	81.10	5.00
Al_2O_3	12.43	15.58	15.41[2]	16.82	27.34	19.43	15.48	22.46	2.61	.43
Fe_2O_3	2.27	7.24	9.04	15.58	......	14.97[3]	13.79	12.90	3.91	.92
FeO	0.15	1.36		12.08	......					
MgO	0.00	2.11	2.49	3.36	23.24	6.20	8.62	4.07	$MgCO_3$ .25	.07
CaO	tr.	1.81	7.02	2.84	......	6.71	5.47	11.08	$CaCO_3$ 46.00	.32
Na_2O	2.01	6.82	by diff. 4.01	1.98	1.6?	3.93	[4]4.75	by diff. 0.04?	......	......
K_2O	6.73	3.48		1.04					NA_2SO_4K .22	.06
H_2O-	0.41	2.23	5.03	14.52	11.07	......	1.74	7.89	2.79	.73
H_2O+	......	......	loss	......		......	......	loss	Organic	2.92
TiO_2	......	......	......	......	......	......	......	......	8.93	2.92
P_2O_5	......	......	......	......	......	......	......	......	......	......
CO_2	......	......	[1]	......	......	......	......	......	......	......
S	......	......	Cl .18	......	......	......	......	.11	......	......
SO_3	......	......	.04	......	......	......	......	tr.	......	......
Copper	......	......	1.70	......	......	......	......	.14	......	......
	......	......	100.00	100.00	100.00	97.25	100.00	100.00	......	......
	......	......	......	2.78	......	......	......	......	......	......

[1] Loss on ignition.
[2] With TiO_2.
[3] Plus FeO.
[4] $Na_2O + K_2O$.

1. Fresh felsite from Table VII.
2. Diabase porphyrite from Table VIII (original rock of No. 4).
3. Calumet conglomerate slime from J. B. Cooper, Supt. C. and H. Smelter.
4. Calumet conglomerate altered boulder, Wilson. See § 10.
5. Calumet conglomerate altered boulder, Heath. See § 10.
6. Mt. Bohemia gabbro from Table X.
7. The "Greenstone" or largest ophite (Table XIV) I cite old imperfect analysis because better comparable.
8. Osceola amygdaloid slime, from J. B. Cooper, Supt. C. and H. Smelter.
9. Keweenaw soil, from Jackson's report, loc. cit.
10. Lake Superior (Upper Cambrian) sandstone soil. The drop in silica and alkalies and rise in alumina are clear.

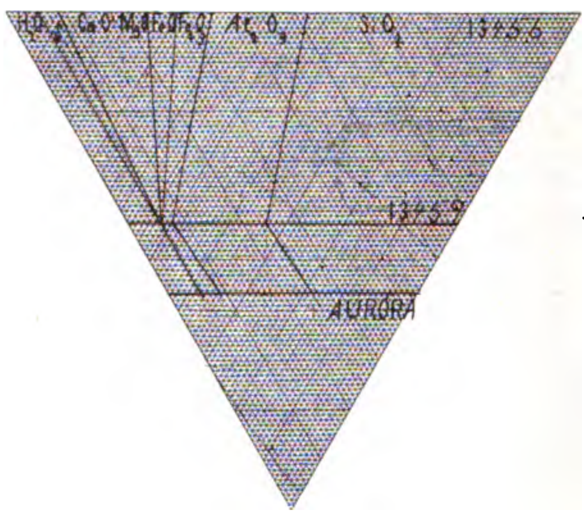

Fig. 15. Diagram illustrates abstraction of material attendant upon the alteration of diabase to kaolin.

TABLE XVIII.

Analyses illustrating kaolinitic alteration.

	1	1a	2	2a	3	4	5
SiO_2	47.99	.83 .800	58.22	.970	47.90	46.85	41.60
Al_2O_3	16.57	.58 .162	28.66	.281	15.60	22.62	37.20
Fe_2O_3	6.01	2.35 .038	2.56	.016	3.69	5.12	3.21
FeO	5.13	23.49 .071	0.22	.003	8.41	1.58	.30
MgO	6.01	.150			8.11	2.01	.02
CaO	9.36	.55 .167	0.17	.003	9.99	1.25	.23
Na_2O	2.00	.032			2.05	.80	.07
K_2O	1.39	.015			0.23	2.66	
H_2O-					.15	3.12	.29
H_2O+	2.64	.25 .148	10.50	.583	2.34	8.25	13.54
TiO_2	2.71	.034			0.82	1.12	3.79
P_2O_5					.13	.16	.14
CO_2					.38	1.89	.38
S					Cr_2O_3 tr		
SO_3					NiO 0.10	.08	
					BaO 0.05	.10	
MnO	tr.				.17	2.54	.08
					100.12	100.15	

1. Mich. Geol. Sur., 1892, p. 141. Analysis by F. F. Sharpless. See also p. 185 and Vol. VI, p. 247-250 and 265. Lake shaft, Cleveland mine. Relatively fresh. 13456.

1a. Molecular proportions. The figures above each molecular proportion indicate the ratio of the ingredient in the fresh and unaltered rock respectively.

2. Same changed to kaolinite.

2a. Molecular proportions.

3. Diabases, Gogebic Range, dike. S. E. Cor. Ces. 13, T. 47 N., R. 46 W. See also Van Hise, Mon. XIX, p. 357, LII, p. 246, Bull. 168, p. 73; Bull. 419, p. 50.

4. Same altered, the pyroxene to hornblende, and hornblende and feldspar to biotite. P. R. C. 1000. Feldspar is also analyzed with .41 K_2O, 3.48 Na_2O, 11.70 CaO.

5. Dike from Aurora mine altered to kaolinite. U. S. G. S. Bull. 168, p. 73. See also Van Hise, Mon. XIX, Part I, p. 265; U. S. G. S., Bull. 419, p. 50, entirely comparable to No. 2. Cf. analyses of water from that mine, taken just over this dike given in Ch. VII § 4.

TABLE XIX.

Keweenawan sedimentaries and the Lake Superior sandstone.

	1	2	3	4	5	6	7
SiO_2	55.09	63.09	69.78	75.19	87.02	82.60	77.18
Al_2O_3	15.41	18.58	15.43	10.78	7.17	8.32	9.69
Fe_2O_3	9.04	2.17	7.93	4.01	3.91	0.28	3.20
FeO		2.73		1.05	....	....	....
MgO	2.49	2.67	1.17	0.95	.06	0.18	1.48
CaO	7.02	1.11	.49	2.36	.11	0.55	0.26
Na_2O	4.01 diff	4.54	2.42	1.93	.22	....	0.18
K_2O	....	.54	2.64	0.93	1.43	6.49	4.67
$H_2O—$	5.03 loss inc. CO_3	2.69	2.61	....	tr.	0.99	2.90
H_2O+				....			
TiO_2	....	.99	....	....	....	....	....
P_2O_5	Cl. .18	.12	....	....	....	0.05	0.21
CO_2	....	....	....	....	....	....	....
S	.04	tr.	....	....	....	....	....
Cu	1.70	.008	....	....	....	SO_3 0.31	0.23
Pd	....	tr. +	....	....	....	....	....
MnO_2	....	.22	....	....	....	0.13	....
	....	....	100.36	....	99.92	....	....
Sp. Gr.	....	....	2.431?	....	2.18	....	....

1. Calumet conglomerate slime undoubtedly is low in felsitic material and one should add to it a proportion of material like the analyses of Table VII. The analysis is nearly that of a mixture of felsite and amygdaloid slime.
2. Nonesuch formation. White Pine drill hole 34 at 500 feet, black chloritic slate. Analyzed by C. R. Guysander, Cochrane Chemical Co. Appears to be a black sand concentration largely of debris as compared with 3 and 4, as shown by the increase in amount of soda and magnesia, and ferrous iron, and alumina.

   In 3 and 4 iron is probably oxide and hydrate, and lime carbonate. The characteristic difference as against Lake Superior sandstone is the lower potash, but there is a gradual transition.
3. Coarse red sandstone. Leighy's on Bad River, Ashland Co. Analysis by E. J. Sweet, Wisc. Geol. Sur., III, p. 350. The Sp. Gr. given evidently includes the pores.
4. Point Houghton, Isle Royale red sandstone. Isle Royale Minn. Geol. Sur., Bull. 8, p. XXXIII, G. S. No. 555. See also 10th annual report, 1882, pp. 49-54. This was marketed as Isle Royale brownstone by Burchan & Co., 117 Griswold St., Detroit.

5.		Marquette brownstone, Sharpless in Wadsworth's report, Mich. Geol. Sur., 1893, p. 157.
6.	Lake Superior sandstone	Portage Entry redstone, Sharpless in Wadsworth's report, Mich. Geol. Sur., 1893, p. 157.
7.		Basswood Island, Apostle Island. Sweet Wisc. Geol. Sur., III, p. 350.

CHAPTER III.

MICROSCOPIC PETROGRAPHY.

§ 1. HISTORICAL INTRODUCTION.

The mineralogical microscopic petrography of the fresh unaltered Keweenawan rocks is not very complicated. Here again as in the chemical work the most thorough and excellent recent work has been done by Alexander N. Winchell.[1] But notes will be found in the annual reports by F. E. Wright, Gordon and myself. The older work of Wadsworth, Irving[2] and Pumpelly[3] was excellent for its time and a number of other papers are cited by those authors, and need not be repeated here.[4] Suffice it to say that almost all the work on this subject is found either in the United States, Wisconsin, Minnesota or Canadian Survey reports and that all these Surveys have done work upon Michigan rocks as well as upon the rocks of their own region since the development of the copper industry has been much greater in Michigan, thus affording better chance to study the rocks. My own work on the petrography is largely incorporated in Vol. VI of these reports and since then I have done comparatively little microscopic work that brought out new mineralogical facts. Perhaps the most interesting is the recognition of a peculiar aegrite or acmite in a Keweenawan dike rock cutting the Virginia slates.[5] I would call attention to the early use in Volume VI of Becke and Exner's method of determining differences of refraction (p. 154). One may grasp a popular idea of this method and its later improvements if one will hold a bottleful of water close to a window at one side. Then one will see that the light coming in from the window suffers total reflection on the further side of the bottle from the window. Thus any object obliquely illuminated lying in a medium of less re-

[1]Etude mineralogique et petrographique des roches gabbroiques de l'Etat de Minnesota, Etats Unis, et plus specialement des anorthosites. 1909. Mineralogical and Petrographic study of the Gabbroid Rocks of Minnesota; and more particularly of the Plagioclasytes. American Geologist, XXVI, 1900.

[2]Copper Bearing Rocks of Lake Superior, Monograph V. U. S. G. S.

[3]Lithology of the Keweenawan or Copper Bearing System. Wis. Geological Survey. Vol. III.

[4]Bibliographies seem unnecessary in view of those issued by the U. S. G. S. as bulletins, but I would call attention to Tight and Herrick's work on Michipicoten. Bull. Denison University. Some additional titles are given in an appendix.

Rominger's section descriptions are given in Vol. V., Pt. I, F. E. Wright's work is in the report for 1908 of Mich. Geol. Survey.

G. Lincio's paper, Neues Jahrbuch für Min. (XVIII) p. 155, I do not find listed.

[5]Report for 1908, p. 304.

fraction (if the border between the two media is anything like the bottle) will have a similar effect,—a bright border on the side opposite to that from which the source of light is. It must be remembered that the field of view is reversed in the microscope so that the effect is apparently reversed. If the index of refraction of a grain immersed in a fluid is clery close to that of the fluid, it may very easily be seen that for certain wave lengths the index of refraction will be greater than that of the fluid, for others less. Then those rays for which the index is greater will have, just like the bottle, a bright border on the side furthest from the source of

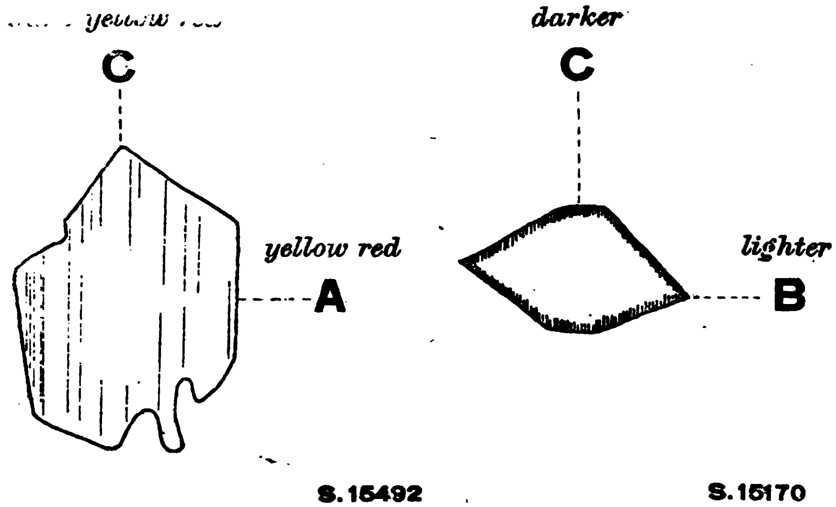

Fig. 16. Illustrates optical properties of altered olivine. Reproduced from Vol. VI, Part 1, Figure 23.

light which will, however, be distinctly colored. If, instead of being a bottle, it is a bubble which is surrounded by a fluid of higher index the bright spot will be on the side nearest to the source of light, as may also be easily seen by shaking up the fluid in the bottle and watching the effect on the bubbles, and if the fluid is so near the index of refraction of the immersed grain for some wave lengths above and others below we shall have the bright border on the far side for one color and on the near side for another. Practically the grains will be bluish on one side and yellowish on the other. This method has been worked up very elaborately lately by Schroeder Van der Kolk and F. E. Wright of Washington and a series of fluids with different indices put up so that by a little study one can tell whether a grain is above or below in

index that of the various fluids and thus determine its character. Not only that, but if, as is generally true, the polarizer of the petrographic microscope allows the light to go through only in one direction,—by revolving the grain we get the index for different directions much more closely than heretofore.

It has seemed, on the whole, best to place the detailed microscopic descriptions in connection with the various cross-sections, from which the specimens have come. We may also refer to the paper by F. E. Wright in the report for 1908, papers by N. H. and A. N. Winchell above cited, etc. The fullest set of (1000) thin sections were made from the Isle Royale drill holes. These sections cover the range of textures so perfectly that it has seemed needful to cut only occasional microscopic sections since, a list of which will be found elsewhere. Beside those cut for the Survey I have had cut personally from forty to one hundred of the Cape Mamainse and other Keweenawan, but not Michigan, rocks.

§ 2. MINERALS.

Olivine is the oldest of the essential minerals. When it occurs it is most conspicuous near the margin of dikes and tops of flows. It tends to be corroded in which case augite seems to grow at the expense of it. When there is less lime there is more olivine developed. Its alteration (Isle Royale Report, Figs. 23-29) may be to serpentine. Occasionally it is to talc or brucite. Another line of alteration is that of oxidation in which it turns red (Fig. 16) and passes into a series of ambiguous minerals variously known. The iddingsite of Lawson is similar. Rubellan was a name much used by Rominger and Pumpelly.[6] The mineral described as bowlingite by Winchell seems to be the same substance or at least very similar. Biotite, perhaps, and hematite unquestionably also occur.

Augite. As I have said in Volume VI, when the augite is scarce it is idiomorphic, lighter in color and appears to be diopside (sahlite). When more abundant it is poikilitic or ophitic as explained and illustrated below. Winchell has described the augite of Pigeon Point very thoroughly and has given an analysis. (Cf. Chapter II, Tables 5 and 14).

It will be noticed that this analysis is not unlike the analysis of most of the diabases and ophites, differing mainly in having more ferrous iron magnesia and titanium. Winchell calls it pigeonite and writes me that it probably also occurs elsewhere in the Keweenawan rocks.

[6] In Mss. corrections Pumpelly changed "rubellan" to chlorophaeite."

There is very often a tendency toward idiomorphism even in the ophitic texture. This is sometimes entirely imperceptible in thin sections but on studying the flashes from a specimen showing the luster mottling it will often appear that they are elongate parallel to the vertical axis, or bounded by straight lines which have a definite crystallographic meaning. A slight tinge of violet such as is given by titanium is especially common in ophitic augite. The more markedly titaniferous kinds are rare. Decomposition of augite to chlorite is very abundant but I do not think that all the chlorite replaces augite. Some of it seems to occupy original interstices left vacant or filled only with hot water in the crystallization and shrinking of the augite. Epidote also replaces the augite. Hornblende seems to replace augite only in a very few cases and then mostly when an augitic rock has been metamorphosed by injection with some later intrusive. There is a zone of hornblende developed from the augite around the Mt. Bohemia gabbro as described by Wright on page 375 of the annual report for 1908. (See also Vol. VI, p. 73.)

Feldspars. I have determined feldspars mostly by the method illustrated on Plate V, Volume VI.[7] Almost always one can find sections cut nearly parallel to the clinopinacoïd (recognizable by the sharp lines between the albite lamellae) in which there are at least three different directions of extinction and in such cases either from the curves given in Plate V or from those given in Rosenbusch's "Microscopic Physiography,"[8] or Winchell's "Optical Mineralogy" one can tell pretty nearly what the feldspar must be. I owe to F. E. Wright a set of fluids ranging in refraction from that of augite 1.523 to that of anorthite 1.58 by which also the feldspars can be readily determined in a powder.

Quartz and other forms of silica. Very recently quartz has assumed a much greater interest owing to the fact that it has been found that silica crystallizes in three different forms according to the temperature and these limits are pretty carefully determined. I regret that most of the work was done before the methods determined by Mügge and Wright and Larsen were developed so that I am not able to speak as definitely as I should like about this matter. Tridymite has never been found, but in such old rocks it probably would in any case have been changed to forms more stable at low temperatures by this time.

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[7]By a careless error this plate reads % of Ab instead of An, and the lines connecting ends of extinction curves with percentage scale are not accurately drawn. I think that these errors in the published plate do not affect my printed determinations (certainly not in most cases) as they are copyist's errors.
[8]p. 359, Fourth edition (1905).

There is, however, little question from the form of the quartz in the quartz porphyries that much of that crystallized between 550 degrees and 800 degrees C. The vein quartz like that described by Lincio[9] was formed at lower temperatures.

Opaque Minerals. Magnetite is generally in octahedral grains though very often they are more skeletal-like in their form. It not infrequently occurs when it seems to be the product of oxydation accompanying hydration. In the typical melaphyres or cross-grain it is often clear that it formed after the feldspar as it is indented by the feldspar laths. If I were going to do my work over again and make a large number of thin sections I think I should pay especial attention to the abundance and form of the iron oxides. It seems also to form as a by-product of the alteration of olivine to angite and thus occurs in the rock forms crowded into the interstices between the patches of augite. In the Isle Royale report (p. 162) by a slip of the pen I wrote "olivine" patches.

Something that may be taken for magnetite is widely distributed as a fine dust, but it is by no means certain whether it is or not. In one dike north of Bessemer there seems to be both graphite and magnetite present under conditions which make it extremely hard to tell just how much is magnetite and how much graphite in thin sections. I think the graphite is more feathery. In alteration spots and around amygdule cavities it gathers into club-shaped and branching aggregates and sometimes iron oxide outlines brecciated and fragmental and perlitic textures. Distinct crystalline and red hematite is more rare. Ilmenits or titaniferous iron ore occurs and occasionally its white alteration product known as leucoxene. This seems to occur also in some of the epidotic replacements. Ferritic discoloration gives to the sedimentary beds and to the red amygdaloids their characteristic color.

Green decomposition products or viridite. There is an old name, —viridite,— which is a convenient one for the secondary hydrous magnesian silicates of green color, which probably form an isomorphic series. Their optical properties have been fairly fully discussed in Volume VI, Part I, and also by Winchell in his recent text-book on optical mineralogy. It is probable that ferrous iron is a very important constituent of the group. I can readily distinguish the three following varieties:—(1) Serpentine with its usual properties after olivine, (2) delessite or iron chlorite, probably including such varieties as strigovite, etc. This is more bi-

[9]Neues Jahrburch (1904) Beilage Band XVIII, p. 155.

refringent and more fibrous than (3) the ordinary chlorite. Chlorastrolite, as Hawes says, seems to be a compound product of some alteration which is changing to chlorite the hard amygdules of some other substance, often prehnite. Chlorastrolite has been found recently not only in Isle Royale on the patch indicated in my map of Isle Royale, Pl. I, where it was originally found but in a number of beds on Keweenaw Point. For instance, a good deal was developed in the workings of the Keweenawan Copper Company at the Medora shaft, and it has been recognized by Dr. Hubbard at a number of places on Keweenaw Point. It there occurs in an amygdaloid which is reddened and decomposed, in which the decomposition has gone on faster in the body of the rather coarse amygdaloid than in the amygdules. Under such conditions a change takes place around the borders of the prehnitic amygdules. In view of what we know of the concentric character of amygdule filling, however, it is not always easy to prove that the green chatoyant effect of chlorastrolite is not due to an original rind of chlorite. Again, the centers of the amygdules are sometimes occupied by quartz and I should not wish to say that thomsonite or some other zeolites may not sometimes be the original mineral rather than prehnite. A. N. Winchell* (p. 410) seems to be inclined to think that some "chlorastrolite" of northern Minnesota should be grouped under thomsonite. In any case the chemical reaction seems very much that which we have found to be characteristic of decomposition, for instance, of the Calumet and Hecla boulders where magnesia and iron replaces lime and perhaps soda.

Laumontite is well characterized and its optical properties are fully given by Winchell. It customarily has a reddish tinge and tends to disintegrate to a sawdust-like powder. This ready loss of water probably accounts for considerable variation in its optical characteristics. Its index of refraction, however, is always low and it seems to be, on the whole, more of a mineral to occur in cracks in joint-planes and the decomposition of the rock directly from them.

Thomsonite. In casual examination of drill cores I may have often confused this with a pink fibrous radiating prehnite which also occurs. Mesolite and other zeolites may have been overlooked.

Wollastonite? In the Amherst mineral collection there is a piece of considerable size labelled "table spar, Isle Royale" in Jackson's own handwriting as Professor Emerson informs me, and of this he was kind enough to give me a small piece. I think there

* Optical Mineralogy, p. 410.

can be no doubt that this is the same mineral as that referred to in his report on page 491 or at least the Isle Royale variety of it.

The Amherst specimen is perfectly white, hardness 6 and more, color snow white, as though it had already been heated. The Sp. Gr. I found to be less than 2.7, the index of refraction (by immersion in a series of fluids) is about 1.56, the bi-refraction is .022 and more, judging by the polarization colors (assuming thickness not greater than breadth.) It seems, as seen through the microscope under crossed nicols, that the granular aggregate is not entirely homogeneous but largely in irregular patches and as Winchell says for Jacksonite, the elongation seems to be positive, the extinction angle practically zero. It does not, therefore, precisely agree with any other mineral but on the other hand there seems to be some confusion between this "table spar" or "Wollastonite" and Jacksonite.

This Isle Royale table spar agrees with the Wollastonite of the Cliff mine except in shade of color, that being light flesh red. With a hardness so much *above* that of Wollastonite and its refraction *less* it can not be that mineral. Since the microscope shows that it is an aggregate I do not care to give it a new name. Dana says that the anhydrous prehnite or Jacksonite is only calcined prehnite (conceivably by some severe forest fire?). Perhaps the table spar is produced in the same way. If the analysis is right (Table VI) I know of no known mineral that it is likely to be. The following is a letter from Prof. Ford.

New Haven, Conn., Oct. 28th, 1910.

My Dear Prof. Lane:

We have four specimens in the Brush Collection of so-called table spar from Isle Royale. One specimen has a Smithsonian label with it which reads "Jacksonite" and has also a label attached to the specimen which says, "Jacksonite and Compact Table Spar." Then there are three other specimens identical in character which Prof. Brush has labeled pectolite. What the material really is I won't venture to say but it is unquestionably not wollastonite. I have asked Prof. Brush about the specimens and some of them at least came from Whitney and are the original material.

Most sincerely yours,

WM. E. FORD.

Calcite is abundant in large crystals and amygdules, in replacement and in veins. Bands of pressure twinning are not uncommon

but may, of course, be due to the pressure in the process of preparing thin sections. It is very abundant as a cement in the conglomorates but it has been suggested that it is more common near the surface than in great depths. Rocks charged with calcite are frequently poikilitic, large patches disseminated from the rock extinguishing together and having common cleavage. This produces a luster mottling which must not be confused with that due to augite.

Epidote. This mineral is one of the most common secondary minerals. The ferriferous canary yellow variety, *not* the zoisitic variety, is best developed. It occurs in veins in the fragments and cements of the conglomerates and in amygdules, and is very common and the association with quartz is rather characteristic. It is often in sharp crystals.

Datolite occurs mainly in rocks which are quite highly decomposed. It is one of the later minerals after copper, more commonly after quartz and epidote. I had a section cut (sp. 20359) of some datolite from the Winona mine which is studded with minute crystals of copper and separated from the chloritic country rock to a large extent by a thin film of copper.

Nodules of porcelain-like datolite from the Franklin Junior Mine similarly show the copper more abundant near the margin.

Copper. When in microscopic size, copper seems to occur in minute cubes or octahedra although the hextetrahedral and other forms have been noticed in the large crystals described by E. S. Dana and frequently found in mining.

Mica. The micaceous minerals, shading into chlorite and sericite or talc on the one hand and micaceous iron oxide on the other, which occur in the decomposition of olivine and have been variously called iddingsite, rubellan, and bowlingite, which is defined by Winchell as a ferriferous antigorite, are fully described by A. N. Winchell. Winchell says that goethite,—the hydrated iron oxide which always occurs after olivine,—has a higher refringence, while the iddingsite like all the serpentine group has a much lower refringence than the olivine. Unfortunately, I have not kept track of this throughout my work but my impression is that most of the brown specks which have been called rubellan in microscopic work by Pumpelly, Marvine, and Rominger and which I have heretofore called iddingsite, have a relatively low refraction and should be classed as bowlingite. It is quite clear in comparing Winchell's description (p. 360) with my description (p. 155)[10] that we are dealing

[10]See Isle Royale Report. Figs. 23 and 29, and Fig. 16 of this report. Also A. N. Winchell, "Optical Mineralogy," pp. 359-360.

with very similar substances, except that in his figure and in mine different pinacoids seem to have been present.

Clay and *kaolin.* The clay of the fluccans has almost no action upon polarized light and is a very finely divided aggregate.

Apatite seems to be a mineral which crystallized early in sharp needles, or possibly slowly throughout the process of crystallization but has a strong tendency to segregation. Possibly the little needles simply floated in the residual magmas. It also seems to occur abundantly in the interstices in the last crystallizations from the mother liquor in needles shooting across the cavities. It suggests the presence of chlorine in these waters (See Sp. 17530, a doleritic melaphyre, 75 paces N., 1050 W. of the S. E. 1/4 of section 33, T. 57 N., R. 32 W., below the Kearsarge amygdaloid in the Allouez gap).

Fluorite has been noticed but very rarely (Isle Royale, Mamainse) and then always in association with the porphyries or salic rocks. The very low refraction and the well-marked cleavage are characteristic and there is a tendency to irregular blue pigmentation.

Sulphides are, on the whole, extremely rare. In fact, I think I have seen disseminated pyrite only when I suspected or was sure of contact action. Chalcopyrite is noticeable, for example, along some of the lines of contact of apparently intrusive felsite at Mamainse, and also near the Mt. Bohemia intrusion in the Calumet and Hecla Mendota section. I have not identified the more basic sulphides and arsenides which offer a splendid field for metallographic work.

§ 3. TEXTURES.

The texture of a rock is defined by Iddings as "the appearance which is derived from the mineral compounds and from the ground mass of dense or glassy rocks," and is divided by him into three features or factors,—(1) the degree of crystallization,—the crystallinity, (2) the magnitude or size of the crystal,—the granularity and (3) the shape and arrangement and mutual relations of the crystals and amorphous parts. This he calls "fabric." The discussion of the relative coarseness of grain or granularity has been of especial interest to me since the recent introduction of testing by diamond drill cores has given unusual opportunity to study the change in texture and granularity as one passes from the margin to the center of the flow and this change in granularity is of very great help practically. It is not possible to separate, altogether, in discussion these three factors since we find that, gen-

erally speaking, near the margin the rock is likely to be more glassy and less crystalline, finer grained and with a different fabric. For instance, in many of the melaphyres the feldspars are distinctly thinner near the margin. There are, however, a few general remarks to be made concerning the texture or fabric before discussing the granularity in detail in Chapter IV.

(1) *Crystallinity.* In rock so old as the Keweenawan rocks it would be hardly expected that very much glass would remain. It is, indeed, rare that one can assume the presence of glass now, although there are many places in which it once existed and not infrequently small areas where it may perhaps still linger. It is not an easy question to say whether the change from glass to crystalline character is devitrification of a secondary nature which occurred ages after the formation of the rock or whether it may have taken place almost immediately, the glass having formed or having been kept at a temperature where devitrification could go on (that is, in the temperature of annealing as the glass manufacturers call it). Especially, where a glass forms close to the margin it may have been kept at a fairly high temperature for some time owing to the source of heat being in the center of the sheet. This is especially true when the outside or contact zone was allowed to heat up. Suppose, for example, an intrusion suddenly entering cold rock; it is quite easy to imagine in this case a rind of glass forming as the intrusion comes in and it is also quite easy to imagine a devitrification later, that is to say, as the contact zone heats up, the margin will be kept at a temperature where crystallization can go on. At the same time the material will be so viscous that the velocity of crystallization will be greatly checked and we shall have a peculiarly fine grained character. This is true, for instance, for a few inches of the Bad River gabbro sill exposed north of Bessemer. (See report for 1906, pp. 488 to 491.) Near the margin there are a few inches very fine grained and then it passes to a very coarse grain, perhaps extra coarse, very suddenly.

This is to me a reasonable explanation, not only of this fine grained marginal form of gabbro, but of some of the felsite ground masses, and it is a question whether a rock of this sort should be classed as originally crystalline or a devitrified rock. The irregular distribution of minerals or gases which tend to promote crystallization through the magma and their irregular escape also produce differences in crystalline texture, even after the rock for many purposes may be considered as solid,—for instance, capable of fracture. Whether indeed we may ever speak of a glass as absolutely

free from viscosity is a question over which physicists would disagree although there is no doubt that in many cases the viscoscity is practically infinite.

(2) *The fabric.* In my Isle Royale report, I divided the textures into two groups according as they were characteristic of the central or marginal parts of the flows and we might also divide them according as they were characteristic of the salic or femic magmas and according as they were characteristic of the deeper seated or effusive forms. In this classification we may distinguish the following textures:

(a) *Central, femic, mainly effusive, ophitic.* This term I have used to denote a texture in which augite acts as cement or matrix and large patches often enclose idiomorphic feldspar in which the lateral pinacoid (brachy-pinacoid) is best developed and often the direction of the brachy-axis. An important feature of this texture is the fact that the feldspar has its form sharply developed against the augite. A. N. Winchell is inclined to lay the main stress upon this and thus broaden the use of the term ophite. His authority for so doing is derived from the first paper of Michel Lévy,[11] introducing the term, in which he uses the term ophitic. His arguments for his usage are given in the Bulletin of the Geological Society of America, Volume 20, pages 661 to 666. On the other hand I published quite a discussion in a foot-note on page 227 of the Isle Royale Report, of the two definitions, and in the Bulletin of the Geological Society of America, Volume 18, page 648, I gave a short note on the ophitic texture to accompany some illustrations from lantern slides of the ophitic texture as I understood it as a variety of the poikilitic, following the definition given by Michel Lévy in his "Structures et Classification des Roches Eruptives," page 28. The facts seem to be that Michel Lévy has used the term in a broader and in a somewhat narrower sense and that there has been fairly continuous use by two schools,—one using it in the narrower sense which will be found quoted on page 227 of the Isle Royale report. I translate it. "When the last element consolidated is a bisilicate (generally pyroxene) its areas without their own proper exterior form are larded with older crystals. Those of the feldspar notably are elongated in the direction of the edge between (001) and (010) and are flattened parallel to (010), and the ensemble takes a characteristic appearance which I have described and figured since 1877 under the name of ophitic texture." In the earlier paper upon which Winchell relies we find that more stress is laid upon the

[11]Bull. Soc. Min. Francaise, Vol. VI, 1878, p. 157.

fact that the pyroxene "moule"[12]—acts as a mould or matrix for—the feldspar and the relative size of the two is not mentioned at just that point.

A few pages later, however, in the same article[13] he says "le minéral le plus charactéristique des ophites est le diallage en grands plages"—the most characteristic mineral of the ophite is the pyroxene in large areas.

Now before we settle upon the use of terms, the facts so far as they are known should be clearly in mind. In the first place, if we take a rock like the Greenstone, having the typical poikilitic ophitic texture in the middle of the flow where large areas of augite include perhaps hundreds of little feldspars, we shall find that in following the texture to the margin the augite decreases in grain much more and more regularly than the feldspar so that at a certain distance from the margin, while the feldspar still remains sharply defined in its own crystalline form and idiomorphic against the augite, it will no longer be true that several feldspars will lie in one grain of augite, but different grains of augite may be crowded in to fill in the spaces between the feldspars so that in the same flow there will be transitions from a texture which is ophitic in the narrowest sense to one which is ophitic only in the broader sense.

Secondly, it will be also found upon comparing effusive and intrusive rocks that at least for the Keweenawan series there is a strong tendency for the feldspar to be relatively finer grained and the augite relatively coarser in the intrusive rocks. Thus while we occasionally find an ophitic texture in the narrower sense in intrusive dikes and sills, they have more predominantly the ophitic texture in its broader sense.

Moreover, in such intrusives it at times happens that while the plagioclase remains lath-shaped, the interstices are not filled wholly with a matrix of augite but with a eutectic intergrowth of quartz and feldspar.

The ophitic texture in the narrower sense is, then, more characteristic of the effusives. In both cases near the margin we find a gradual transition to a partly glassy or, as it has been called intersertal texture. But a matrix, glass or crystalline, of augitic composition seems to me important.

The probabilities are that it will be found a rather desirable thing to emphasize the relative size of the feldspars and the pyroxene and if ophitic in the broader sense is to be used to replace

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[12] Fits the feldspar as dress of the present fashions fit the female form. I notice the word used in that connection in French. A. C. L. 1909.
[13] Loc. cit. p. 169.

the term diabasic we may have to introduce some new terms to replace ophitic in the narrower sense. In Idding's discussion of poikilitic texture[14] he recently proposes to subdivide the poikilitic texture, calling the matrix crystals, the oikocryst and the enclosed crystals chadacrysts, and giving a series of terms from per-oikic to per-chadic, according to the relative abundance and the relative size of the two. They may come in use. It is possible that some such term as poikilophitic may prove to be desirable and necessary, but it must be remembered that the rocks I call ophite and ophitic would also be called ophitic by A. N. Winchell, and in Rosenbusch's last edition (Vol. II, Pl. 4, Fig. 4) the illustration of ophitic structure is an admirable illustration of ophitic structure in the narrower sense in which I use it. It does not seem wise for me to make a change from my previous usage just now, especially as on the whole it seems to me that Michel Lévy, though he has used the term in both senses seems really to have the narrower sense mainly in mind and simply included rocks to which the broader term more directly applies when they occurred in connection or as transition forms from the narrower sense. One must, then, remember that in this report the terms ophite and ophitic also imply luster mottling if the rock is fresh and the grain coarse enough. I would have kept the term luster mottled melaphyre, were it not very cumbersome when one wishes to add further descriptive adjectives and repeat the expression over and over again, as we must in the detailed sections.

A luster mottled texture is often visible in hornblendic rocks when it probably is a relic of the same texture in an originally augitic rock. For instance, just south of the road from Ishpeming to Negaunee about three-fourths of a mile east of Ishpeming is an amphibolite with 10 mm. poikilitic patches that I take to be an inheritance from an ophitic augite texture. In the contact zone of the Mount Bohemia gabbro and I think also in some coarse luster mottled rock south of the Porcupine Mountains the derivation in this way can be readily seen for we find the patches of augite changing to hornblende round their margin so that there is a rim of hornblende with an augitic less lustrous center.

The augite seems to drive the corroded remnants of olivine before it in its growth. I suppose, too, that any interstices which were left would be between the different crystals of augite which seem to have been the last consolidation in a typical ophite. Thus when the rock is altered or exposed to weather the centers of the au-

[14] "Igneous Rocks," p. 202.

gite patches are the last to be affected and are left as knobs on the weathered surface as shown in Plates II and III of this report (see also Vol. VI) and as may be readily seen almost anywhere on Keweenaw Point but especially well on the Greenstone Range itself. This same knobby appearance is very characteristic at Mamainse in a heavy bed on the north side of Sand Bay. On matte surfaces, such as pebbles or joint planes or diamond drill cores there is also a mottling,—the augite centers being often somewhat lighter as seen against a darker green chloritic or reddened ground (Pls. IV and VI) but the exact color pattern may vary. The weathered portions may sometimes be browner. One can thus with a little

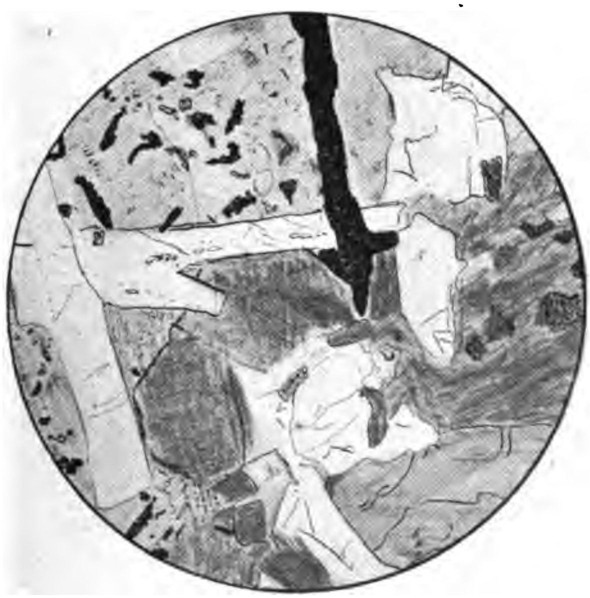


Fig. 17. Illustrating original cavities in rock of the copper bearing series such as may have been originally filled with gases. In the figure they are wedged in between feldspar laths and octagonal augite,—characteristic of the doleritic texture panidiomorplin. Reproduced from Figure 7, Annual report for 1903, p. 245.

training recognize without any thin section the gradual increase in grain of the augite, and the rocks which show this mottling are very monotonously the same, even under the microsope differing, so far as I can see, but slightly. Some have a little more or little coarser olivine remnants. Occasionally this ophitic texture may be combined with large feldspar phenocrysts (eocrysts). This is true sometimes in the foot of the Kearsarge lode and occasionally in the Greenstone itself.

A very good large colored diagram of the ophitic texture is given

in Irving's Monograph,[15] Plate IX, which shows pretty well in black and white reproduction (Pl. IV. c). Before leaving the subject of the ophitic texture it may not be inappropriate to mention its derivation from the Greek word for reptiles—ophidians—and in Plate IV a I reproduce for comparison a photograph of a Gila monster which Mr. Jesse Myers kindly took for me.

(b) *Doleritic* (Pl. VII, Sp. 17998). This term I used in the Isle Royale report for a texture in which the feldspar was much coarser relative to the augite than is generally true in the ophite. The term *doleritic* has always been applied to rather coarse grained rocks of the basaltic and diabase families. A recent suggestion has been to apply it to rocks of these families in which the feldspar can be easily recognized with the eye or the lens, while hornblende or pyroxene cannot. This is the definition suggested by Iddings, Chamberlin and Salisbury in their Geology, Volume I, p. 417, and adopted by Pirsson ("Rocks and Rock Minerals," p. 198). It is obvious that my definition of the texture is not out of harmony with this macroscopic definition since if the feldspar could be recognized and the pyroxene not, it would be likely that the feldspar would be relatively coarse, though perhaps not really in larger grains than the augite, since it is easier to recognize feldspar with characteristic twin striations than to separate augite from hornblende. It is, however, true that I have applied the term "doleritic texture" and "doleritic streaks" in my descriptions of the cross-sections (cf. Isle Royale, drill hole III, Sp. 15126) to specimens which Pirsson might call "gabbro," e. g., that figured in Plate VII, that are so coarse that both the feldspar and the augite can be distinctly recognized by one who is practiced. The fact is that one will find in the heavier beds (more frequently in some than in others) streaks which appear to be almost sharply separated from the rest of the rock. In many cases they might readily be taken for intrusions and yet if one will study one will find that there is a definite connection between their coarseness and the coarseness of the surrounding rock, and that they never occur very close to the margin,[16] and will, I think, finally conclude that they are due to some sort of differentiation by which some of the ingredients have gathered together in the process of cooling and produced a magma more favorable to the coarse crystallization of the feldspar. This may be due to some such action as that which produces a stratification banding in water with very finely divided clay slowly settling in it,

[15] U. S. Geol. Survey, No. 5.

[16] Though occasionally, e. g. in Bed 35 of the Clark-Montreal section (Chap. V. § 2) it seems as through the hot welding of two flows had given a doleritic texture. The original contact representing a cooler streak in the joint bed should be extra coarse in grain.

but I am more inclined to think that it is due to the accumulation of some sort of mineralizer, say water vapor, or the like, in certain layers. There may be a distinct tendency toward separation of the water bearing and non-water bearing magma. In some of the large exposures of the Greenstone, say back of the Central mine, one will find broadly curved bands of lighter and darker color, which appear like the stratification of some gneisses, but these are evidently nothing more than eutaxitic flow lines, possibly marking some initial slight difference in temperature which has been rendered permanently visible by slight differences in the abundance of certain crystals. The phenomena are very well described (and without any such theoretical preconception as might tempt me to warp my account), by Marvin in his description of the light and dark kinds of diorite by which he cuts the "Greenstone" up into the different beds of his Eagle River section 91 to 108.[17] All of these belong to one immense flow. That feature Marvin does not seem to have grasped. He describes two types,—the light type and the dark type, and these alternate over and over again. Beds 90 to 91 represent the finer grained ophite near the margin and Beds 92 and 93 a coarsely mottled rock of the ophite type; from Beds 94 to 106 there is a pretty regular alteration of what he calls the "light type" and the "dark resinous type,"—the light being what I should call "doleritic," the dark resinous type being the "ophitic" or "luster mottled." This is, however, the coarsest possible illustration of the texture in a rock which might be by many considered as a gabbro, *but if so it is an effusive gabbro.* The feldspar here in the light type is long and, as he says, at times over an inch in length. The plagioclase twinning lines are so coarse that he noticed them. He suggests that the relative proportions are 40 to 54% feldspar, about 40 to 46% (he calls it hornblende) augite, and considerable delessite (including the altered olivine?) It has a coarse crystalline, irregular texture with numerous segregations of coarser material composed of prehnite and feldspar and quartz and epidote, all suggesting a rock originally rather porous. and my explanation is that in the process of the crystallization the gaseous mineralizers, being collected in certain streaks, produced a coarser crystallization of the feldspar and a more open miarolitic or interstitial character. These interstices may be lined with borders of fibrous chlorite or chalcedony. The main filling may be as described by Marvin or the interstices may be filled with chlorite and quartz, apatite needles, and various specks

[17]Vol. I, pt. II, pp. 133-137. Van Hise and Leith doubt that they are "one flow."

of iron oxide. Against them not only is the feldspar sharply bounded by the augite but may often be seen to have its crystalline form. Figure 7 of Report for 1903, herewith reproduced as Figure 17, illustrates this, and Figure 3, Plate VI of Volume VI which is a photograph, not a drawing, shows the same thing, not so sharply and more or less disguised, with a tendency toward an agglomeration of the feldspar. Close to the center of the field and a little down to the left is a cavity between three fairly large feldspar crystals which is lined with the fibrous chlorite rind. The filling of these interstices might properly be called secondary but in some cases, no doubt, the filling began long before the rock had lost its original heat. Indeed, it may have been pretty closely associated with the original cooling. If I am right in thus regarding these streaks and this texture it is a superficial equivalent to deep-seated pegmatites and similar rocks. The tendency to this doleritic texture seems to be characteristic of some beds more than of others and these doleritic streaks appear at times to be fairly persistent. Some engineers have correlated from drill hole to drill hole by them, but if I am right as to their origin such a correlation is unsafe. Yet their presence is a pretty sure sign of a rather heavy flow and correlation can often be made by this fact.

One thing I would emphasize before leaving this subject and that is that while the grain varies in these doleritic streaks and is not always uniform as compared with the more luster mottled rock in which they may often occur, yet after all, in a broad way they too, are coarser the farther they are from the margin of the flow, and whereas near the margin we may find little doleritic streaks in which the feldspar is two or three millimetres long, in the larger flows it may be several millimetres or as Marvin says an inch. The characteristic feature is not the absolute size of the feldspar but its size relative to the augite and to the feldspar of the surrounding, not doleritic, rock. To this we may add the tendency toward idiomorphic character in the augite and open interstices. For illustrations of this tendency of the doleritic streaks to be coarser in the coarser flows, and coarser near the center of those, see Beds 112 and 116 of the Central mine section, Belt 42 of the Clark-Montreal, as well as the "Greenstone," especially in its upper part.

Illustrative Cases of Relation of Coarseness to Distance from Margin in Doleritic Texture.

	Thickness of flow.	Distance to margin.	Length of grain of feldspar.	Location.
Central Mine:				
Bed 112	205	6	2–3 mm.	d. 7.648
Bed 116	270	81 100	6–8 mm. 10 mm.	d. 7.804
The "Greenstone" Manitou Section 3 N. (Fig. 29)	1130	*	3 mm. 6 to 8 5 mm.	d. 3.74 3.99 3.161
Sp. 17998			6 to 8 12	3.220 255
Mandan Ophite.	475	116 172	4 mm. 10 mm.	d. 12.136 192

* About same as depth in hole.

(c) *Glomeroporphyritic or navitic.* (Pl. VII, Ss. 15384, 15295). The appearance under the microscope of this texture is illustrated in Figure 4 of Plate VI of Volume VI and also in Rosenbusch's Figure 1 of Plate IV of Volume II, though that is not really highly characteristic. In Irving's Monograph, Plate IX, Figures 2 and (especially) 3 this texture may be represented. It is characterized by the fact that the feldspar occurs with very considerable range of size and the larger feldspars tend very strongly to gather together into bunches or clots. To this the word *glomeroporphyritic* applies, which we may paraphrase as agglomerated porphyritic or clotted. Iddings well calls it seriate porphyritic. The origin of the texture seems to be in the fact that there was a considerable excess of feldspar molecules in the cooling magma so that the feldspar crystallized before the magma came to rest, and grains stuck together more or less. The feldspar growth seems to have been continuous and these larger feldspars which rolled in from perhaps a cooler point in the course of the flow may be toward the margin considerably larger than in the grain which would result from the very last consolidation. (Cf. Pl. VII.) In a glomeroporphyritic flow there may thus be a very considerable hiatus between the two kinds of feldspar near the margin and an almost continual series toward the center with every gradation between what Iddings calls the seriate and hiatal fabric. These feldspars do not seem to be radically different in chemical composition or widely separated in time of origin from the latter feldspars. Nor are they generally speaking corroded. They are what I have called rhyocrystals and not brotocrystals. Larger and distinctly hiatal crystals with no transition to the crystals of the ground mass do, however, occur and are characteristic of certain beds. One of the most important

of these is the foot wall of the Kearsarge lode. (Pl. VII, Sp. 17956, and Mandan d. 18 at 90 ft.) The glomeroporphyritic is a type of texture which occurs especially in the Ashbed series; for instance, in the beds near the Pewabic worked by the Quincy mine, but some signs of this texture occur all through the series in many of the more feldspathic melaphyres, especially in a group below the Wolverine sandstone in the Central mine section, Beds 97-115, in the Torch Lake Mining Company section, Beds 30-59, Holes 4-7.

(d) *Porphyritic hiatal.* (Pl. VII, Sp. 17956 and Mandan d. 18 at 90 ft.) We have just spoken of this texture in contrasting it with the glomeroporphyritic. It must not be imagined that in this texture feldspar individuals do not occasionally group themselves together. Almost all plagioclase is a group of twins, but in this texture the difference in size and shape and sometimes chemical character between the crystals of the older generation and the crystals of the younger is much more marked than in the glomeroporphyritic or seriate porphyritic texture except possibly near the margin of a flow, for in the latter, where fine grained, very close imitation of the hiatal porphyritic fabric may be found. The fabric I have now in mind is one in which the porphyritic feldspars are found several millimetres, in fact at times centimetres long, while the feldspars of the ground mass may not be recognized with the naked eye. In fact, such rocks are very likely to have a peculiarly fine grained blue-black, dense, aphanitic ground mass and such blue-black traps can often be recognized even when phenocrysts are not present. In other words, these rocks are distinctly magnophyric in Iddings' use of the term, while the glomeroporphyritic rocks are normally, but not always, mediophyric.

All the above textures apply primarily to the basic or femic rocks. The salic rocks have their own textures but so far as the phenocrysts are concerned all are much more porphyritic hiatal. Though the phenocrysts may be of any size they are usually sharply distinguished from the ground mass. The ground mass of the felsites is usually a fine grained mosiac of quartz and feldspar but sometimes the quartz becomes poikilitic by simultaneous extinction showing an orientation over areas which include a lot of other things enclosed, such as feldspar and iron oxide. Not infrequently these poikilitic quartz areas surround phenocrysts of quartz as with an aureole or halo. I am inclined to believe that these textures of poikilitic quartz are due to secondary alteration of an originally glassy ground mass. Coming now to textures involving more especially ground mass:—

(e) *Amygdaloidal* texture (Pl. VII, Sp. 17956) is due to gas bubbles more or less filled. These bubbles are abundant at the margins and tops of flows. Occasionally large ones seem to occur also well in toward the center. It is not infrequent to find beds of fine grained red mud or ash filled with what seem also to be practically amygdules produced by the turning of the water in the mud to steam through the heat of some overlying bed. The bubbles are larger and rounder in the ophites, smaller and finer and often more drawn out in the more feldspathic rocks. Around the amygdules, as near the margin of the flow, the grain becomes finer; the feldspar assumes forked and skeletal forms such as are according to Tammann[15] characteristic of crystallization which takes place quite a little below the fusion point. From the bottom of a flow these bubbles may rise up in long tubes, the so-called pipe amygdules. Such pipe amygdules are well exposed, for instance, in the bluffs just north of Bessemer. Thus there may be a little of the lower part of a bed which would be classed strictly as amygdaloid,—generally, however, not over a foot or two. In the various sections it has been found convenient and necessary to assume that the top of the amygdaloid was exactly the top of the flow.

(f) *The microlitic* texture which occurs around amygdules and elsewhere is shown in Figure 5 of Plate VI, Volume VI, and in the plate already referred to in Irving, and in Figure 5 of Plate III in Rosenbusch's Physiography. It is characterized by the fact that the last generation of ground mass is composed of feldspar in minute needles perhaps something like 0.1 millimetre long and very much more slender. Instead of being tabular they are more likely to be prismoidal.

There are a number of textures here which may perhaps be distinguished but which are so closely alike that it is hard to describe the difference. Many of the melaphyres have close to the margin a microlitic texture when the augite remains still in the glassy form. This also occurs around amygdules. In either case there is really more feldspar in the rock and so we get feldspar porphyries with a very similar texture. In the extreme marginal forms, however, the feldspar microlites are almost invariably forked and are inclined to enclose glass and assume skeletal shapes, and are perhaps on the whole a little less likely to be regularly arranged. This is perhaps the hyalopilitic texture proper and may be found in most of the sections which are cut within a few inches of the margin. I have never seen it when the record implies that it was more than a foot away from the actual exterior of the flow.

[15] Kristallisieren und Schmelzen, Leipzig, 1903, pp. 134-135.

On the other hand, a texture which is rather characteristic of the feldspar porphyries is liable to have the feldspar somewhat coarser and especially to have the feldspar crystals arranged in somewhat parallel flow lines. A particularly good illustration of this is found in a feldspar porphyry which seems to cut an ophite in the Mendota cross-section.

(g) *The vitrophyric* texture (generally glassy ground mass) seems usually to be confined to a few millimetres from the contact. In the femic rocks, the melaphyres and porphyrites, this is probably as far as it went. In the felsites and salic rocks it extended much farther. In the basic rocks it is brown and yellow and seems to be largely decomposed.

(h) *The normal crystallization* of the quartz feldspar eutectic, if it crystallizes directly from aqueous solution in the first place, seems to be in the rock intergrowth which I have called micropegmatite. A good adjective perhaps is *graphic*. The texture is beautifully illustrated in Iddings' chapter on the "Crystallization and Texture of Igneous Rocks." When microscopic, Iddings calls it micrographic. This micrographic texture occurs in the interstices of the Bessemer gabbro and the center of most, if not all, of the large diabase dikes.[10] It also occurs in some of the porphyries. It is also very common in the pebbles found in the conglomerates. It is so much more common there than in the igneous rocks that it is a strong argument in favor of Wadsworth's view that it may be a secondary texture of the same nature as the poikilitic aureoles of quartz and the quartz feldspar mosaic of the felsite. Irving agreed with Wadsworth in his interpretation. I can not personally agree with that interpretation, for reasons explained quite fully in my discussion of the quartz diabases and the granophyric diabases (which Iddings would call the graphophyric diabase), in my Isle Royale report, but the relative abundance of this texture in the pebbles is certainly puzzling. Can we assume that it is primary and also secondary in the presence of hot water?

(i) Another texture of the salic rocks is the *spherulitic or microfelsitic*. In some of the porphyries near the Bare Hills described by Hubbard, the rounded balls, known as spherulites, occurring in the felsites are very well shown. These also occur in the Porcupine Mountain porphyries. It is due to the rapid growth of quartz feldspar eutectic from centers of crystallization in a salic magma and is sometimes, perhaps always, a microscopic or submicroscopic radial intergrowth of quartz and feldspar aggregate in the micro-

[10]See Vol. VI., Pt. I., Pl. XVI and report for 1908, Pl. VII.

graphic texture. This is very fully and beautifully described by Iddings.

(j) Another texture characteristic of the salic rocks is a granular aggregate of quartz and feldspar, none of the grains being peculiarly elongate and the general effect being that of a *mosaic.* This occurs in the gabbro aplites and is pretty surely primary. I am inclined to think that a very similar texture but without quite so much sign of crystalline form in the grains also occurs as a product of secondary alteration. This mosaic texture is then sometimes pan-idiomorphic and sometimes hyp-idiomorphic. The general appearance is equi-granular. (Report for 1908, Pl. VII, Fig. 5.)

(k) Before leaving the subject of textures one texture which is charactertistic of the sediment should be mentioned, that is the *tufaceous* in which the peculiarly concave forms of ash is well illustrated as shown in Figures 1 and 2, Plate VI of Volume VI. The original fragments are found entirely replaced and may be charged with epidote, but before this change they may have been coated with chalcedony from the large amount of soluble silica which necessarily occurs in a glass deposit which then persists so that after their original substance is all gone their form may yet remain. This leads to one further texture.

(l) It will often be found that between crossed nicols there are large patches which extinguish together, are generally quartz full of enclosures, and have no relation to the texture as seen in ordinary light, in which latter case one may perhaps plainly see the outlines of feldspars arranged in some microlitic or trichitic texture. Upon changing to polarized light there will be no sign of this texture remaining. This is a *secondary poikilitic,*—metapoikilitic texture.

In the Isle Royale report I separated the petrographic notes from the general cross-sections. It has on the whole not proved a satisfactory method and in this report I have placed petrographic notes with the general notes where they naturally come in describing the cross-sections. The most complete and systematic set of thin sections are from Isle Royale drill cores. Since then sections have been made only as some special point of interest came up. The following list of specimens may with the index help one in knowing what specimens have been collected or sections studied from various horizons.

§ 4. LIST OF SPECIMENS OF KEWEENAWAN FROM SP. 15000 ON.

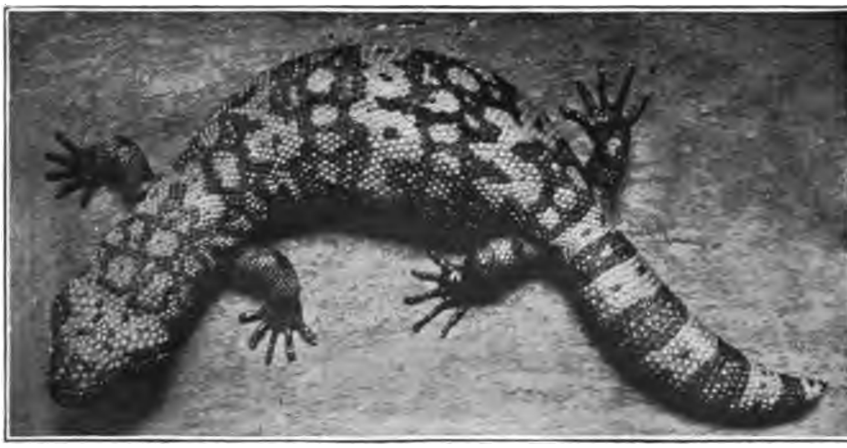
Ss.	15000-16000	are from Isle Royale and mainly sectioned. The sections are in the Ashbed and Central Mine group of flows. Up to 16400 they were also from Isle Royale, mainly not sectioned.
Ss.	16401-16473	are from Tamarack No. 4 shaft. Down to 16445 mainly Ashbed group, down to 16457 above con- mainly Ashbed group, down to 16457 above Conglomerate 14. (See Annual Report for 1903.)
Ss.	16474-16482	and 16490-16500 and Ss. 16515-16534 are Tamarack No. 3 shaft down to the Allouez Conglomerate No. 15 at 16500.
Sp.	16483	is from Tamarack No. 5 shaft, continued by 17654-17686.
Ss.	16541-16564	are from Centennial cross-cut, Calumet to Osceola.
Ss.	16650-16676	are from the Central Mine. (Fig. 31).
Ss.	16677-16679	are from Eagle Harbor, section 23, T. 58, R. 31.
Ss.	16780-16782	are from the Copper Falls Mine.
Ss.	16873-16880	are from T. 58, R. 32, Ashbed group.
Ss.	16906-16907	are from Copper Falls, Central section.
Ss.	16908-17057	are from the Lac la Belle and Mendota section (See Vol. VI, Pt. 2,—a number of thin sections).
Ss.	17058-17132	are from a long cross-cut from the Quincy Mine running below it in the lower Ashbed and Central Mine groups. Only one section 17066,—an ash.
Sp.	17133	is from Keystone Location. (Sec. 30, T. 58, N. 37 W.) sectioned; also 17213-4; otherwise—
Ss.	17134-17236	were further specimens in T. 58, R. 28, for Hubbard's work on Bare Hill, etc. (Vol. VI, Pt. II.)
Ss.	17275-17342	are from the Franklin Junior section (See Vol. VI, Pt. II) continued by
Ss.	17343-17448	Mt. Bohemia rocks for L. L. Hubbard (see Vol. VI, Pt. II).
Ss.	17449-17551	are along lines of contact with occasional sections. Porphyry, melaphyre, dolerite, ophite, amygdaloid, felsite, tufa.
Ss.	17552-17553	are from Section 33, T. 58 N., R. 31 W.
Ss.	17554-17635	are miscellaneous specimens.

Ss.	17636-17653	are from Franklin Jr. cross-cut (See 20429). Figure 40.
Ss.	17654-17686	are from Tamarack 5 shaft.
Ss.	17686-17689	are Gratiot Bluff felsite.
Ss.	17690-17695	are near South Range near hill north of belt.
Ss.	17695-17715	are various specimens in Ontonagon district, a
Ss.	17715-17865	few of them sectioned. 17705 is a glomeroporphyrite.
Ss.	17866-17871	Copper vein, prehnite, melaphyre boulder.
Ss.	17878-17899	Atlantic Mine cross-cut. Chapter V, § 16.
Ss.	17899-17991	Franklin Jr. (See 17342) section and drill holes sections Nos. 17982, 17991. Figure 40.
Ss.	17992-17999	Drill cores, Manitou holes.
Ss.	19401-19703	are between Winona and Rockland, described by P. S. Smith, typewritten. A few thin sections have been made with notes by Lane.
Ss.	19704-19775	West of Ontonagon.
Ss.	19735-19740	Old Colony cross-cut. Chapter V, § 10.
Ss.	20039-20340	Black River section with Gordon's notes. (Report for 1906.)
Ss.	20351-20354	Ashbed group on south side of Portage Lake, Section 35, T. 55 N., R. 34 W.
Sp.	20356	Sectioned eastern sandstone, Wyandotte drill hole 13. Chapter V, § 21.
Sp.	20357	Amygdaloid conglomerate, Wyandotte drill 9.
Sp.	20358	Sectioned, epidotic sediment, Wyandotte drill 5.
Sp.	20359	Section of datolite, Winona Mine.
Ss.	20380-20427	Superior trench and shaft. Chapter V, § 14.
Ss.	20429-20442	Franklin Junior, 4th level cross-cut, of Section 17653. Ch. V, § 11.
Ss.	20443-20446	Franklin Junior, 21st level cross-cut. Ch. V, § 11.
Ss.	20447-20458	Miscellaneous illustrative specimens from various locations.
Ss.	20461-20485	Manitou section.
Sp.	20485	M. 3. 122.
Ss.	20486-20500	Mendota ophite and intrusive felsite porphyrite.
Ss.	20501-20559	Mount Bohemia.
Ss.	20560-20562	
Ss.	20563-20598	Torch Lake sections, 20575 Minong type. Ch. V, § 10.
Sp.	20600	Altered boulder of Calumet and Hecla.

Sp.	20601	Copper and silver from Old Colony lode.
Sp.	20602	Calcite and copper in two generations.
Ss.	20617-20620	Diamond drill core set, used in Plate VI, from St. Mary's Challenge exploration.
Ss.	20623-20638	Calumet and Hecla White Pine explorations.

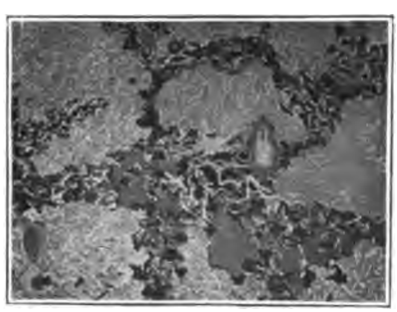
Descriptions of the following thin sections will be found scattered through the text.

Sp.	19086	
Sp.	17982	Steamed sediment.
Sp.	17998	(Oligoclase Ab An.). Into the hanging of the Pewabic Lode.
Sp.	20356	The earlier sandstone. Marvine's Conglomerate 6-8, or sediment.
Sp.	20358	Wyandotte Hole 5 at 307.
Sp.	20359	



(A.) PHOTOGRAPH OF AN OPHIDIAN, THE GILA MONSTER, TAKEN BY JESSE MYERS OF THE ZOOLOGICAL DEPARTMENT OF THE MICHIGAN AGRICULTURAL COLLEGE.

(B.) OPHITIC MOTTLING BROUGHT OUT NEAR A SEAM OF CHLORITE FROM THE MANITOU SECTION 3 D. 3 N., AT 543 FEET DEPTH; IN THE GREENSTONE, THE BASE OF WHICH IS ABOUT 72 FEET AWAY. THE DIAMETER OF THE CORE IS 7-8 OF AN INCH.



(C.) THE EFFECT OF OPHITIC TEXTURE IN THIN SECTION, HALF-TONE REDUCTION OF PLATE IX, MONOGRAPH V, U. S. G. S., BY R. D. IRVING. FROM A MELAPHYRE IN THE SOUTHEAST QUARTER OF SECTION 9, T 51, R 12, MINNESOTA, ENLARGED ABOUT 4.7 IN DIAMETER.

TRACKS (?) ON SLAB OF NONESUCH SHALE, PHOTOGRAPHED BY J. T. REEDER. DIMENSIONS OF SLAB ABOUT 10 X 14 INCHES.

CHAPTER IV.

THE GRAIN OF THE IGNEOUS ROCKS.

§ 1. INTRODUCTION.

This chapter logically belongs with the chapter on microscopic petrography but the grain or coarseness of many of these rocks can be made out without the use of the microscope. Since its variation has practical importance and as I have made some especial study on the same, it has seemed to me best to make a separate chapter of my studies.

Igneous rocks, as their name implies, have been formed through the loss of heat, aided or retarded by changes in pressure and included gases (mineralizers). Treat heat or caloric (the ancient phlogiston) as an imponderable substance, and we may group it with the gases as a solvent, and say that consolidation is largely or wholly due to diffusion of solvents through the margin. In other papers[1] I have discussed the general theory of the matter, but as some of them are out of print and the report for 1903 is defaced by a number of errors in printing, I will give an abstract here correcting some errors but omitting details.

The Keweenawan rocks most often occur in dikes, sills, sheets and lava floods,—forms, one of whose dimensions is so much less than the others that the position and distance from the margin in this direction is the important factor. It is not the only important factor, for the chemical character is, of course, of fundamental importance. The more viscous (practically the more feldspathic) the magma, the finer grained. The process of growth may be stopped in one of two ways, either the available molecules are exhausted or the magma becomes so viscous that they can no longer be pulled out. In the former case it may be simply that the rock is all consolidated and wholly crystalline, the mineral in question being the last one formed. It may also be that the remaining molecules are soluble at a given temperature and pressure and may go into entirely different crystal molecules, and indeed the crystals formed

[1]Bull. Geol. Soc. Am., Vol. VIII. (1896), pp. 403-407; Geol. Rep. on Isle Royale (Geol. Sur. Mich., Vol. VI., 1898), pp. 106-151; Am. Jour. Sci. (4), Vol. XIV. (1902), pp. 393-395; Bull. Geol. Soc. Am., Vol. XIV (1903), pp. 369-406; Ann. Rep. Geol. Sur. Mich. for 1903 (1904), pp. 205-237; Do. for 1904 (1905), pp. 147-153, 163: Am. Geol. Vol. XXXV. (1905), pp. 65-72; Jour. Canad. Mining Inst., Vol. IX; "Die Korngrösse der Auvergnosen," Suppl. to Rosenbusch Festschrift (1906); Report Geol. Sur. Mich. (1908); U. S. G. S. Monog. LII, p. 407.

may be redissolved. For instance, we find plain indications in the Keweenawan rocks that a magnesium silicate forms as olivine at high temperatures, but that if the part molten rock remains near certain lower temperatures long enough the olivine already formed may be corroded and augite molecules formed instead. Thus for a certain distance in from the margin the olivine may be sharp and conspicuous, and farther in may be only in corroded grains.

One important factor, however, will be the rate of cooling. For as the rock fluid or magma cools it tends to become more viscous and that retards both the formation of centers of crystallization and the flow of molecules to them and in general for a given composition of rocks the slower the cooling the coarser will be the grain. In the viscous feldspathic rocks the power of crystallization is low. Hence feldspathic rocks are extra fine grained. On the other hand augitic rocks of a composition something like Bunsen's normal basalt are always visibly granular within thirty feet of the margin. Felsites in similar masses will be recognizable by their porcelain-like fineness.

The retention of solvent gases seems, as we have mentioned in discussing the doleritic and ophitic or poikilitic texture, also to aid the power of feldspar crystallization, so that the last formed feldspar is likely to be coarse relative to the augite in intrusives, pegmatites and doleritic streaks. On the other hand, it appears that the surface melaphyres flowed and kept pretty well stirred up in temperature until they were cooled to within 10 per cent of the crystallizing point of augite, and that consolidation took place from the margin to the center before the center had cooled much,—for the grain of the augite (as theory would lead us to expect in such a case) increases from the margin to the center. Theoretically, we should find that there could be a rapid rate of increase proportional to the distance from the margin for a short side zone which was crystallized before the adjacent rock had heated up appreciably and there would then be a transition (fairly sharp) to a slower rate of increase. This, if the degree of superfusion is small, and the initial temperature not over 5 per cent more than the crystallization temperature, will continue from the margin to the center and be proportional to the distance from the outer margin of the contact zone. The augite of the Keweenawan melaphyres which crystallized really followed these laws to a rough degree of numerical accuracy. The contact zone and rapid rate of increase is confined to a belt usually less than ten feet. The inner rate of increase (which I have called A, the outer C′) is fairly uniform for any

one flow[2] and in the lustre mottled melaphyres or ophites is usually between 1 mm. in 10 and 1 in 20 feet, or say 1 mm. in 3 to 5 meters. In the more feldspathic flows, like the Kearsarge foot, it is less. The maximum rate of increase must depend on the ratio of viscosity and consolidation. The very highest inner rate of increase is a rate of 1 mm. for each 8.5 feet, but in the large majority of cases the rate comes out 1 mm. in somewhere between 11 and 16 feet. This refers to the linear diameters of the augite grains as indicated by the mottlings on the drill cores. (Pls. IV and VI.)

§ 2. GRAIN NUMERICALLY DEFINED AND RECOGNIZED.

To take up this matter more precisely, while we know that some rocks are coarse grained and some fine grained, just as grocers sell coarse and fine granulated sugar, it is not at all necessary that all the different minerals that make up a rock should be of the same grain. This is not generally true. It is also quite possible that in comparing different parts of one rock mass, one mineral may be coarser, another finer. Whether this is so is a matter of observation. In any precise work the grain of one mineral must be considered at a time. Still it is a matter of common observation that some rocks like pegmatites have a generally coarse effect, others mineralogically alike, aplites say, are generally much finer grained.

The coarseness of grain of a given mineral may be determined by the linear dimensions of its crystals or by the areas covered by them in cross-section.

Practically, it is generally more rapid and convenient to compare linear size,[3] though the areas appear to vary more directly with the slowness of cooling.

The grain of a mineral may then be determined by taking the average of breadths of the grains. I have sometimes used the average of five of the grains (making sure of full-sized ones and not working on clipped corners, by taking the largest within a given area large enough to include numerous grains, like the field of view of the microscope, or a square centimetre, etc.). Another way of measuring the grain is by varying magnification. If one section, magnified five diameters, appears as coarse as another, we may say its grain is one-fifth as coarse. In the Isle Royale section most of the work was done with a micrometer eye-piece, one of whose divisions was about equal to 1/30 mm. So I took three observa-

[2]Cf. the data found for the Greenstone, especially at the Mandan and Manitou locations.

[3]Rosival (Verh. Wien Geol. Reichs-Anst., XXXII, 1898, p. 143) has demonstrated that volumes are proportional to linear measurements of mineral grains in section, as A. N. Winchell has called to my attention.

tions, for by adding them and pointing off two places one can get the average dimensions in mm. at once.

The grain of a rock we may regard as the grain of characteristic and dominant constituent minerals. If it is to be studied with relation to the margin of an igneous rock it is important that the mineral should be one which formed after the fluid rock magma came to rest. The last formed constituent is generally that which conforms more closely to the laws of cooling, for (1) heat given out by chemical rearrangement is less and (2) even its own latent heat of crystallization is taken up largely by pre-existing minerals and thus disturbs the simple cooling effect less; (3) the abundance of granules already present tends to prevent undercooling and bring on crystallization promptly, as fast as the temperature drops so that it is possible; (4) initial irregularities in temperature are more likely to have been smoothed out.

My most important and interesting results have been obtained on the augite which is the last formed essential ingredient of many of the traps,—those that run about 48 per cent silica and 10 per cent lime, such as are very common in the Keweenaw series. It is the cement or mesostasis.

The size of grains of this augite is often quite readily recognized with the naked eye. Of course it can always be told in fresh rock by examining thin sections under a microscope. It may also be recognized without the microscope:—(1) by the flashes of light reflected from the large faces which extend all over one individual. Rocks so reflecting have been called luster mottled melaphyres and ophites. They are poikilitic. (2) Again the iron oxide and olivine seem to have been crowded away from before the augite as it formed, though the feldspar is enclosed. Possibly there is some porosity between the grains. There should be. Thus the alteration to chlorite and serpentine always begins at the outside of the augite and works in, and as we have mentioned there are color patterns formed which are recognizable to the practiced eye,—sometimes on joint planes, sometimes on smoothed surfaces, whether polished or unpolished, rounded pebbles or as illustrated in drill cores. They are more faint on fresh fractures, but even here there is a faint purple and green mottling often mentioned by Marvine. In general the augite centers are less greenish.

(3) If the rock is exposed to the mechanical erosion of the rain, the interstices weather back and leave a warty, pock-marked appearance so that the rock fifty years ago was called varioloid greenstone. Illustrations of the appearance of the drill cores and of the weathered surface are found in Plates II to VII.

§ 3. GRAIN DEPENDENT ON RELATION TO THE MARGIN.

When igneous rocks occur in elongate forms, over five times as long as thick, the distance from one margin alone need generally be considered. There are exceptions, however, to this, as when gas escapes into a cavity (a bubble which when filled is an amygdule) around which we find in consequence a finer grain. The doleritic streaks due perhaps to segregated mineralizers are other exceptions. Occasionally (Sp. 15743) we find a finer grain near a crack which might be explained by supposing that the rock was a stiff viscous glass and cracked in cooling like the basaltic columns before crystallizing.

When a rock crystallizes there are two factors concerned. The one is the power of crystallization, to wit, the number of crystal granules forming in a unit volume in a unit of time.[4] If, for instance, we heat up a glass above a certain point it will commence to devitrify and the higher we raise the temperature the more rapidly will it devitrify and the more numerous will the specks of crystalline devitrification become. Obviously the number of these will put a distinct limit on the size of the crystal into which any one center may grow. This is known as the power of crystallization.

If the substance has not high power of crystallization it may be cooled so rapidly that it becomes a stiff solid glass and the crystals will not appear at all. Then upon raising the temperature we shall find that at some temperature, often about that at which the glass begins to soften, the crystalline centers appear. The temperature where there is greatest power of crystallization is sometimes considerably below that of perceptible viscosity, sometimes much higher and nearer that of the fusion point. The power of crystallization always seems to decrease near the fusion point, but this must be partly, at least, because the latent heat of crystallization is given out and raises the surrounding fluid to the fusion point and so checks the action. The power of crystallization is not so inversely proportional to the viscosity as the velocity of crystallization.

This second factor is the rapidity of crystallization or linear velocity of growth of crystals in millimetres per minute. This differs in different directions. We ordinarily assume that the planes of cleavage are planes of greatest molecular density. It is natural to infer that in attractions lying in these planes the molecular attractions will be strongest and there will be a tendency to greater growth. This is, indeed, true in a general way. Minerals which

[4]Tammann, G., Kristallisieren und Schmelzen, 1903, pp. 134, 140, 161.

have an ample supply of material generally are elongated and grow out fastest in the direction of cleavage. If there are two cleavages concerned, the direction of elongation is most likely parallel to their intersection. That this is not the only factor concerned, however, and that the mutual attractions of various crystal atoms and molecules play a part is shown by the fact that crystals have different forms when crystallizing from different solutions and that minerals which have very poor cleavage,—for instance, quartz—very often have a marked tendency to elongation. However, it is so generally true that we may rely on it with some confidence that crystals which form rapidly with an ample supply of nourishment are elongate. This is particularly characteristic of the feldspars. Near the margin of a flow the very small and minute feldspars of the so-called microlitic and trichitic texture are, as will be seen from the measurements given in the Isle Royale section, perhaps five to ten times as long as they are broad, and in such feldspars the elongation is often parallel to both of the cleavages. In the coarser feldspars, elongation is likely to be more than three times that of the breadth and the form is more that of a tablet. It is true also of the augite that even in the grains which form the last interstitial patches there may be often discerned a distinct tendency of elongation parallel to the vertical axis and to the cleavages. Now, obviously, if the different individual grains of a mineral are idiomorphic and not interfered with by others their size in different directions must depend very largely upon this velocity of crystallization. This velocity of crystallization is, however, in some cases at least, not independent of the temperature itself. Apparently it increases as the temperature falls below the temperature of saturation or fusion and attains a constant maximum, some five, or according to Doelter's idea, twenty or twenty-five degrees below the fusion point. According to Tammann, however, the velocity is really greatest at or close to the fusion point and the power of crystallization would be greatest were it not for the heat given at the latent heat of fusion, which raises the temperature and thus checks the action. If this heat could in some way be conducted away then the viscosity would steadily increase and the velocity of crystallization decrease continually below the temperature of saturation.

This velocity of growth must depend upon the rate at which molecules can be drawn in, and this in turn must be diminished by the viscosity,—the internal friction of a fluid. The viscosity of a fluid is, indeed, measured in just this way, by the velocity

with which steel balls will move through it drawn down by the attraction of gravity.

We may look at it another way. The temperature of a body depends on the mean velocity of its molecules. As the temperature falls a smaller and smaller number of molecules then will in a given time pass on their paths within the range of a growing crystal where they will be added to it. Tammann's experiments[5] show that the crystals formed while the solution was only one degree to five degrees below the saturation or fusion temperature were larger and less elongate, and bounded by more different crystal forms so as to give on the whole more nearly equal dimensions; that from five to thirty degrees beneath the melting point they become more prismatic and are more regularly arranged with reference to the direction of growth and cooling. At lower temperatures yet, they tend to enclose glass and become forked. This has a direct importance to us for we may infer regarding the augite patches in the ophitic texture that since they are so equant in form they were formed before the magma fell much below the crystallizing temperature and therefore in a very limited range, while on the other hand the extremely microlitic forms of some feldspar crystals near the margin suggest at once that there was a considerable undercooling of the magma before they were formed.

The crystallization of any molten rocks or solution is due to a change in conditions. In the igneous rocks, as the name implies, loss of heat is the important factor. But as we have said it is not the only one. Change of pressure is another. Loss of some ingredient promoting fluidity like the evaporation of water from solution is another. Such an ingredient is known as a mineralizer.

We may remember the three factors as T. M. P., not temperature alone, but temperature, mineralizers and pressure. When we wish to emphasize the conjoint effect of the first two factors we speak of aqueo-igneous fusion.

The effect of loss of pressure may be greatest by indirectly promoting the loss of mineralizing gases.

It may be proved experimentally and theoretically that the slower the loss the coarser the grain, and in particular the slower the cooling the coarser the grain. And it may also be shown that the less the drop, that is the less the difference in conditions between those of crystallization and those of the country rock toward which the molten mass is cooling, the slower the cooling and hence other things being equal the nearer the country rock is to melting the

[5]Kristallisieren und Schmelzen.

coarser the grain. Examples of slow or slight change of conditions and coarse grain are rock candy and rock veins. Pegmatite must be another. Agate cavities have walls lined with relatively rapidly precipitated silica. Often at the center is quartz in larger crystals, more slowly formed as the supply became slower and slower.

Diffusion and loss of gases or mineralizers follow laws like those which apply to the loss of heat. The fundamental principle is that

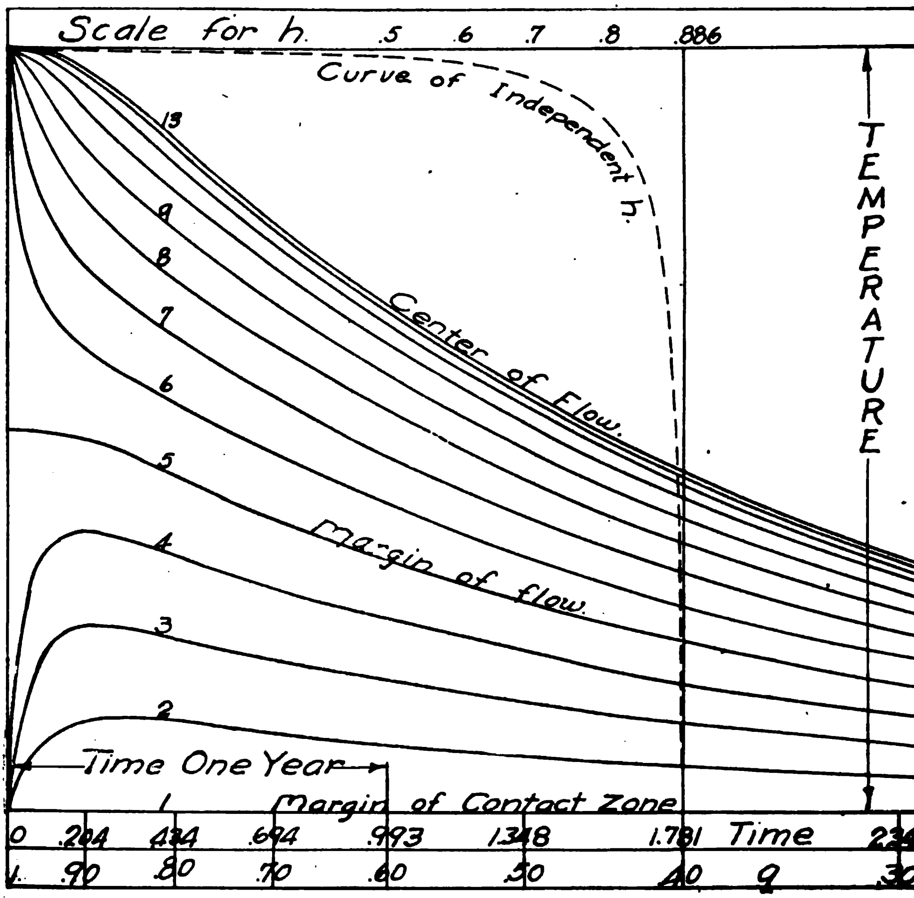


Fig. 18. Curve showing cooling of lava sheet and heating of a contact zone supposed to be one-fourth the breadth of the lava sheet on either side. The abscissa (x) represents the time, the lapse of which is measured from left to right. The temperature for different times is given by a series of curves for a number of points equally spaced from the center of the flow to the margin of the contact zone which is supposed not to be heated at all. It will be noticed that outside the curve for the margin where the temperature begins half way between the initial temperature of the contact zone (which is taken as zero) and the initial temperature of the lava sheet, the curves first rise (as the contact zone heats up) and afterward fall. The diffusivity is supposed to be constant and in getting the scale of time from the curves found as functions of (q) the total breadth (c) was assumed as 100 feet and the diffusivity (a^2) as 400. These curves may be considered as contours of a surface which would represent the connection between temperature (v) time (t) and position (x). There is also given in dots a curve representing the variation of h (see text) with the temperature for early times when it is independent of the time.

if there is at a given point a change of state (for instance, loss of temperature) in time there must be not merely a steady flow, as much transmitted as received, but an accelerated flow or change in space, the amount transmitted being increased over that received by the amount lost.[6]

The general principles have been better expressed by Wright in the report for 1908 than I can phrase them.

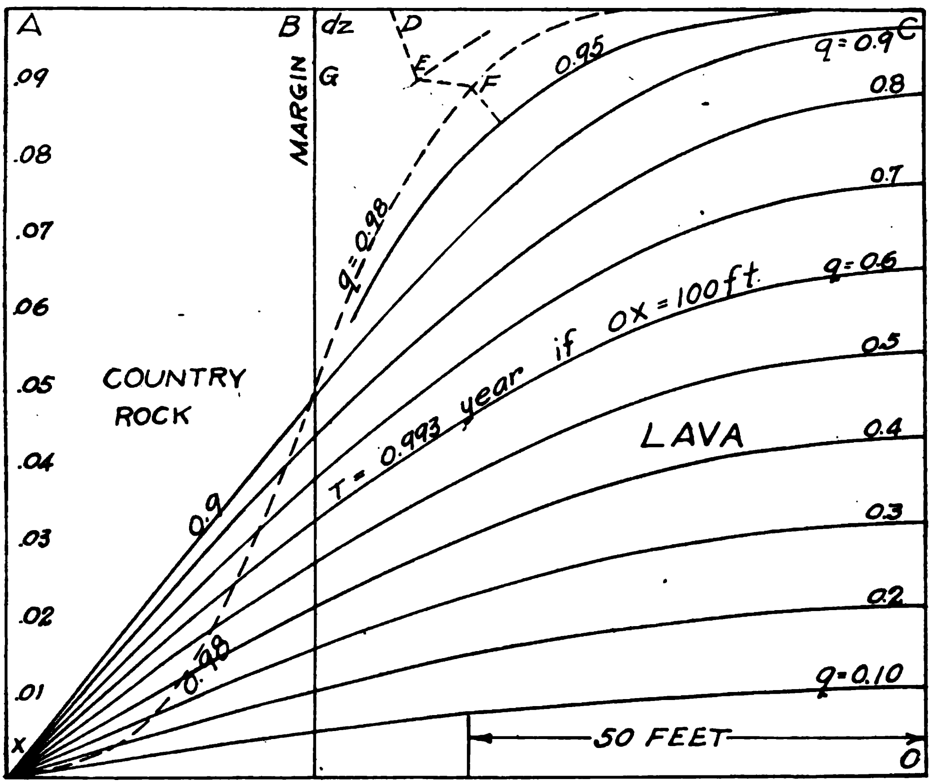


Fig. 19. Shows the cooling of the same igneous sheet as Figure 18 with the temperatures as ordinates but the distance as abscissa, the curves being given for different epochs of time not equally spaced. It may thus be considered as a view of the same surface as Figure 18 looked at from the right hand side. There are also lines showing the effect of varying diffusivity. See text.

The curves showing the temperature at any given time of an indefinite cooling sheet placed between two others which are allowed to heat up but kept at constant temperatures outside can be plotted without any serious difficulty if we suppose diffusivity to be con-

[6]In mathematical notation this statement becomes
$$du/dt = a^2 \, d^2u/dx^2$$
where a^2 is really a function of u and x and t but is generally taken as constant and called the diffusivity.

stant. Such curves I have given among other places in the Isle Royale report (Vol. VI) and in the annual report for 1903 for three different widths of the outside sheets.[7] In this report I give a slightly different set showing the cooling in case the outside sheet, the belt supposed to be heated at the margin, is one-fourth of the total thickness of the hot sheet of rock and one-sixth of the total thickness supposed to be affected. To show the connection between the three variables, temperature (v), the position in the sheet and its distance from the margin (x) and the time (t) requires really a surface which may be represented by contour lines and in Figure 18 and Figure 19 I have given two views of the surface, one in which the abscissa is the time and the ordinate the temperature and the contour curves are equally spaced distances from the center of the flow. In the second figure the abscissa represents the distance from the center of the flow and the ordinate the temperature as before while the curves represent different, *not equally spaced* epochs in the cooling.

§ 4. CRITICISMS.

Now a perfectly fair criticism has been made upon my work by Doelter[8] and Harker,[9] viz., that I have considered in my work on the theory of the variation of coarseness of grain mainly the diffusion of heat, that I have assumed the diffusivity constant and have neglected the importance of such weighty factors as the undercooling and the effect of the giving out and absorption of latent heat which I have just mentioned. It will be found, however, that in my very first paper I noted the fact that the theory was incomplete and I have always found in practical applications that considerable corrections were due to other factors than those which had been mathematically treated and yet it is always necessary in any problem in physics to do just this,—to assume an ideal state of affairs much more simple than the real and then little by little as one finds variation in the real from the ideal to try to apply the necessary corrections. I have found in the augite of the lime melaphyres or ophites and in many other cases agreement enough with the numerical theory to make it of practical and, as I believe, scientific value.

As to the disturbing effect of undercooling and the latent heat given out in crystallization there are certain factors which may

[7] In the curves figured by Queneau and copied unfortunately by Iddings the abscissas are not proportional to the time, but to a function thereof.
[8] Petrogenesis, p. 45.
[9] Natural History of the Igneous Rocks, pp. 219-221.

diminish its importance. One is that the rocks are composed of different minerals so that the effect is distributed at various temperatures. Another is that some of them crystallize quite slowly even when undercooled so that the giving forth of heat by the latent heat of crystallization is distributed. With regard to the very last mineral crystallized, the augite of the ophites say, a large portion of the rock may be already solidified and so only a very small quantity be crystallizing, the heat of which will be absorbed by the whole rock, thus diminishing and diluting its effect. The effect produced can be studied experimentally. Compare the curves of cooling plotted by Vogt.[10]

§ 5. ALLOWANCE FOR VARYING DIFFUSIVITY.

As White has remarked, the effect of crystallization can largely be allowed for by assuming that the diffusivity is not constant. This we know is the case anyway. The diffusivity of a rock changes with the temperature. The change is ordinarily not very great during the important range except in case of crystallization. In this case it is and may be infinitely little. Now if we take the equation $du/dt=a^2\ (d^2u/\ (dz)^2)$ and assume a to be constant and compare it with another equation $du/dt=f(u)\ (d^2u/(dx))$ we can use the solution of the first for the second if we will take the successive values of x so that $f(u)/a^2=(dx)^2/(dz)^2$, that is to say, if we cut up the body into a series of layers parallel to the margin each offering the same resistance to diffusion of heat. These will not be of equal thickness at different temperatures, nor will the total number in a given thickness of dike be constant. But suppose we try to find the connection between these layers and their thickness and the temperature and the position. For this purpose we may take the figure (19) in which curves for the equation with a constant diffusivity are shown with the distance from the center and the temperature (x and t,) as abscissa and ordinate. Let this be the solution for z. At the initial temperature divide off the scale of x into a number of equal indefinitely small parts, $BD=dx=dz$, when $u=v=1$ and at this temperature they will all represent the same diffusivity and the same distance and the same width of successive layers offering the same resistance to the flow of heat. But as the temperature falls the diffusivity will change and if we connect each of the points at the top (e. g. D) with points like E representing the breadth of a layer having the same diffusivity as the

[10] Silikatschmelzlosungen, Pt. II, Pl. 1 and 4; Fig. IV. See also e. g. Fig. 12 of Day and Allen on the "Isomorphism and Thermal properties of the feldspar" showing the distribution of heat absorption in melting orthoclase.

initial layer (BD) the ordinate curves instead of being straight lines and parallel to the vertical axis will vary as DEF shown in the figure and will give us then the corresponding thickness.

If then we take our uz curves for the solution of

$$du/dt=a^2\ (d^2u/du^2)$$

and for each point with a given temperature t shift the abscissa over as given by the zx curve we should have a series of curves to solve the equation $du/dt=f(u)\ (d^2u/dx^2)$ that would be fairly satisfactory, did we but know f(u) and were that fairly uniform, *but for the fact that in solving* $du/dt=a^2d^2u/dz^2$ *and getting these curves we have to use auxiliary equations which involve the scale of* x *and if we suppose it to vary we suppose also to vary therewith the breadth of the dike and its contact.* It is only then in initial cooling where the breadth of the dike is not important and no other factor involving linear dimensions but x and a comes in that this method could be used. We have been using practically a variable scale of distance and thickness that implies that the thickness and width of the igneous mass and contact zone will be variable from time to time and temperature to temperature. This method of solution, therefore, is not sound and can only be looked to in early cooling (and linear increase of grain) for cases in which the size of the mass or contact is of little importance, that is for crystallization which takes place before the center has cooled. Moreover, we know very little about the diffusivity as a function of u. At present and for this report all we need is to note that the tendency of decreased diffusivity is to crowd the curves of Fig. 19 into the corner B and that if augite (the last mineral consolidated) increases in grain clear to the center, much of the crystallization must have taken place in this early time.

The mathematical investigation is therefore of real importance, but may be skipped over lightly by those not especially interested so that they may come to the conclusions, at the end of the chapter.

§ 6. MATHEMATICAL TREATMENT.

GENERAL FORMULAE FOR ROCK GRAIN.

MARGINAL TEMPERATURE FIXED.

In an injected sheet of uniform temperature and diffusivity whose walls are kept at a fixed temperature the temperature may be expressed in two kinds of series, one of definite integrals of the probability integral type, the other the ordinary Fourier series terms; the former most applicable at the early stages of cooling, the latter in the later stages of cooling.[1]

Curves showing the manner of cooling, at first fast at the margin and slow at the center, then later slow at the margin and faster at the center are given in Figure 20.

[1] See Byerly, "Fourier's Series," articles 49-50; annual report for 1903, p. 210 (misprints corrected here); and A. L. Queneau, Am. Jour. Sci., 1902, p. 393.

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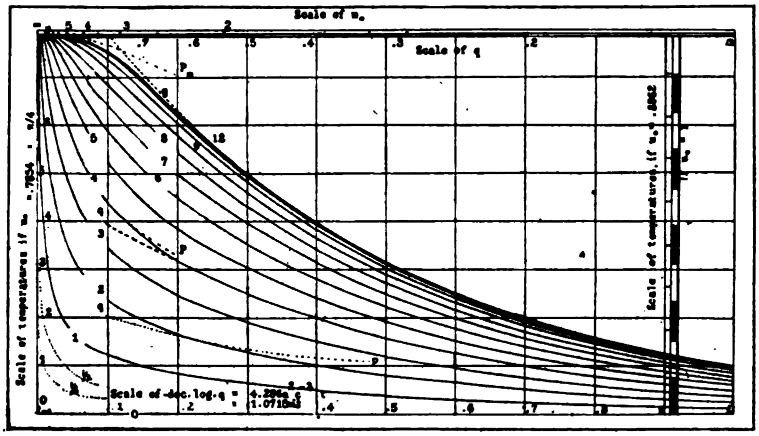


CURVES OF COOLING—MARGIN TEMPERATURE CONSTANT

Fig. 20. This shows the cooling of an igneous sheet, the margins of which are kept at a constant temperature, taken as 0° and represented by the bottom line of the diagram. The temperatures are represented by ordinates, and three different scales of temperature are given, corresponding to different values of the initial temperature. The main scale at the left is the same as used in the Isle Royale report. To the right is the scale if, as is assumed by Queneau, $u_0 = .8862$, and also if the initial temperature of the igneous sheet (that is, its excess of temperature over the surrounding rock) is taken at 1. The abscissas to the right represent the lapse of time, the main scale at the bottom being proportional to dec. log. q and t, and the scales above being proportional to m_0 and q, which are defined in the text. Curves for twelve equidistant points from center to margin are in full lines, and in dotted lines two curves still closer to the margin, one twenty-fourth and one forty-eighth of the distance to the center respectively. Also for curves 12, 4, and 2 we indicate by dashes the points where the curves of approximate solutions (obtained by using the first terms only of equations 1 and 2) leave the curve which we have taken them to represent. This shows the error which we make in using such approximations.

$$(1) \quad \frac{u}{u_0} = P_m - \left(P_{m_0+m} - P_{m_0-m}\right) + \left(P_{2m_0+m} - P_{2m_0-m}\right) - - -$$

$$(2) \quad \frac{\pi}{4}\frac{u}{u_0} = q \sin \pi x/c + \frac{q^9}{3} \sin 3\pi x/c + \frac{q^{25}}{5} \sin 5\pi x/c - - -$$

where:

u is the temperature after a certain time (t);

u_0 is the initial temperature;

t is the time from the beginning of cooling;

x is the distance from the margin;

c is the thickness of the flow;

a^2 is the diffusivity,

$m = x/2a\sqrt{t} = x\, m_0/c$

$m_0 = c/2a\sqrt{t} = c\, m/x$

nat log $q = - \pi^2 a^2 c^{-2} t = (\pi/2m_0)^2$

$P_m = \frac{2}{\sqrt{\pi}} \int_0^m - m^2 dm$ is the probability integral of which there are numerous tables. The report for 1903 and Johnson's "Theory of Errors" contain them.

$\pi = 22 / 7 = 3.1416$

Formula (1) is the Woodward-Queneau formula and converges most rapidly at early times and near the margin when m_o is greatest.

P_m varies but little from 1 if m is much over 2, and for the center cooling that means if $m_o > 4$.

Formula (2), which I used in the Isle Royale report[2], converges much more rapidly for large values of t the time or q. When formula (1) ceases to give a result approximate to the third decimal place, a couple of terms of formula (2) will usually give it. The linear grain will be expressed by the formula (where k depends on the power of crystallization of the mineral under the given conditions and will be *assumed* independent of the temperature and time, except as later provided):

$$(3) \quad g = k\sqrt{\frac{dt}{du}} \cdot$$

For ordinary igneous magmas where probably according to Doelter du is often not over 40° and u_o and u are to be reckoned in hundreds of degrees dt and du may be treated by the infinitesimal calculus or that of finite differences.

In any table of the values of u in the terms of x and t, such as are given in the report for 1903, we find the ratio dt: du as the quotient of the corresponding consecutive differences of argument and functions respectively, for the same value of x.

We deal with the partial derivative of t relative to u, x being supposed constant, that is.

A glance at equation (2) shows, what is not so clear in (1), that it is only the ratios u/u_o, x/c and a/c which are involved in determining t, moreover our tables are not constructed directly with t as an argument, though u/u_o is the function. I found it convenient to express (3) otherwise and introduce instead of t a variable h (and m) where

$$(4) \quad h = \sqrt{\frac{-d(m)/m^3}{-d(u/u_o)/(u/u_o)^3}}$$

Then (3) may be written[4]

$$(5) \quad g = \frac{c\ k}{a\sqrt{u_o}} \cdot \frac{x}{c} \cdot \frac{1}{h\sqrt{2}\,(u/u_o)^3}$$

The advantage of doing this is that h proves to be a rather peculiar function of u, x and t, in that it is for quite a range of temperatures close to $.8863 = \sqrt{\frac{\pi}{4}}$, for a wider range is $\frac{u/u_o}{m}$ and, especially for early times before the center has cooled when u/u_o is practically P_m, is independent of x, and its values are given by the following table, corrected from that in the report for 1903 in which a line unfortunately slipped out.

[2]See Byerly, Fourier's Series, Article 60, ex. 1.
[4]The steps are somewhat more fully given in the report for 1903.

VALUES OF h BEFORE CENTER HAS COOLED.

$P_m = u/u_o$	m	$h = \sqrt{\frac{m^2 D_m u/u_o}{(u/u_o)^2}}$
0	0	$\sqrt{\pi}/4$
.1125	.1	.8863
.2227	.2	.88
.3286	.3	.88
.4284	.4	.88
.5205	.5	.88
.6039	.6	.87
.6778	.7	.87
.7421	.8	.86
.7968	.9	.85
.8427	1.0	.83
.8802	1.1	.80
.9103	1.2	.78
.9340	1.3	.75
.9523	1.4	.70
.9661	1.5	.67
.9763	1.6	.64
.9838	1.7	.55
.9891	1.8	.49
.9928	1.9	.45
.9953	2.0	.39
1.0000	infinity	.00

In Fig. 18, a curve is drawn giving h when it is a function of u/u_o only (for early times) by the aid of which curves of relative coarseness of grain may be obtained readily for various positions and temperatures up to the time where the temperature at the center drops off.

The curves of grain are best located by their tangents and values at critical points. At the margin

(6) $g = C'x$ where $C' = \frac{k}{a\sqrt{u_o}} \cdot \frac{1}{h} \frac{1}{\sqrt{2}\,(u/u^o)^2}$

and C′ is the rate of increase at the margin,—something that may be observed.

The grain at the center (E) we most readily find from equation (2). If there is a belt of uniform grain, (as I remarked in the Isle Royale report) $D_t \frac{u}{u_o}$ is a function of u not varying with varying x. This can be only if in (2) the expansion for $\frac{u}{u_o}$ is practically confined to the first term. For the differentiation of (2) gives

(7) $\frac{\pi}{4u_o} D_t\, u = \sin \pi x/c\ (D_t\, q = -\pi^2 a^2 c^{-2} q)$ - - -

$= -\pi^2 a^2 c^{-2}\, \pi/4\ u/u_o$ if terms after the first are neglected.

This will be the same for a given value of u regardless of x, and from (3) we find — writing E for g and substituting (7)

(8) $E = \frac{c\,k}{a\sqrt{u_o}} \cdot \frac{1}{\pi\sqrt{u/u_o}} = \frac{c\,k}{a\,\pi\sqrt{u}}$

E then should really vary between the value of g derived from Eq. 6 if the increase kept up to the center, that is $\frac{C'c}{2} = \frac{c\,k}{2a\sqrt{u_o}} \cdot \frac{1}{h} \cdot \frac{1}{\sqrt{2}\,(u/u_o)^2}$ and the value just found in (8) which does not depend upon the initial temperature u_o. The

ratio of these two is also the ratio of the distance from the margin at which the grain would be equal to that at the center if the marginal increase kept up (which we may call the belt of marginal increase) to the distance from the margin to the center. It is

(9) $\frac{E}{C' c/2} = \frac{h\sqrt{2}}{\pi u_o/u}$ = about .4 to .5 of u/u_o when the width of the contact zone is inappreciable.

Cf. Figure 21 below.

Marginal Temperature Not Fixed.

When we come to consider the case that the sheet is supposed to have heated a contact zone, a formula which we found in the Isle Royale report enables us readily to construct the curves of decreasing temperature, which are shown in Figures 18 and 19.

This formula is as follows:—If v represents the temperature at a time t of a point at a distance of z from the center of a sheet the thickness of which is 2w with a contact zone of breadth y on either side, so that the whole zone affected or c is equal to 2w+2y. then—

$$(13) \quad v = \tfrac{1}{2}(u_{w+z} + u_{w-z})$$

where u_{w+z} is the temperature which would exist at the same time t after the beginning of cooling and conditions otherwise the same (except that its margins are kept at a constant temperature) in a sheet whose thickness was equal to c at a distance of w+z from the margin and u_{w-z} is the temperature at a point at a distance of (w-z) from the margin in the same sheet. Or if (w-z) becomes negative—that is, the point lies in the contact zone—we must assume

$$(14) \quad u_{w-z} = -u_{z-w} \text{ (in the contact)}$$

Now if we let x′ be the distance of the point in the sheet with a contact zone from the margin of the sheet—that is $x' = \frac{c}{2} - z - w$

$$(15) \quad v = \tfrac{1}{2}(u_{x'} + u_{2y + x'})$$

Thus we can obtain the curves of these figures either graphically (very rapidly) or by taking means of appropriate rows of the table of solutions of the case where the margin is kept at a fixed temperature, a table which is given in the Isle Royale report for an initial temperature of .7854, and in the report of 1903 for the initial temperature of 1.

Thus expressing the grain of the sheet with a contact zone y on each side as a certain function g ( ) of x′ measured from the outside of the contact zone, of v the temperature of crystallization of u_o temperature of injection, of y the width of the contact zone and of k, which may represent such factors supposed to be invariant as diffusivity and power of crystallization, we may proceed to locate curves of relative coarseness of the grain by their values and tangents (rates of change) at certain important points.

At the Center.

Here

(10) $v = u_w$ whence we have

(11) Center grain

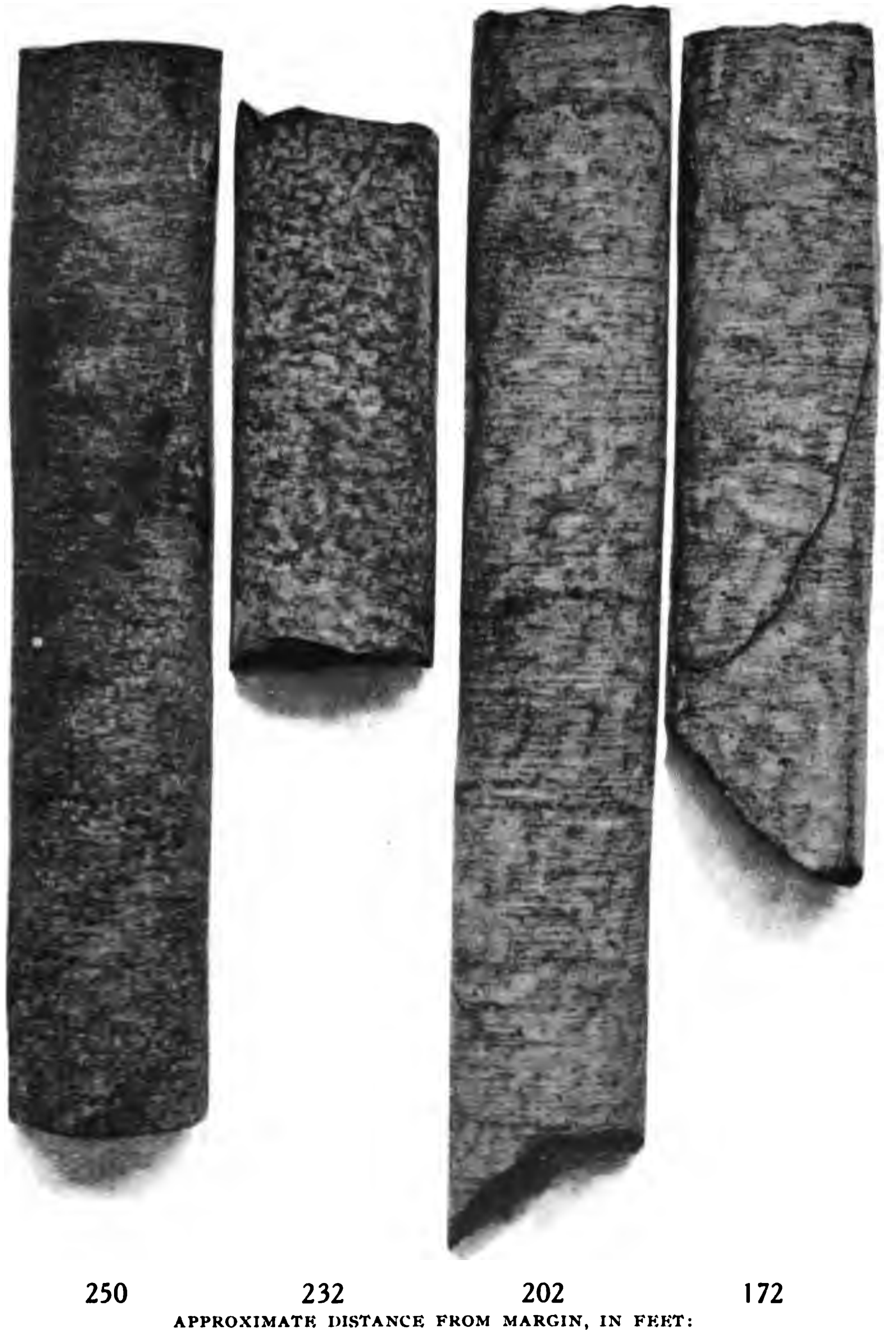
$$g(k, x' = c/2, v, u_o, y, c) = g(k, x = w, u_w, u_o, y = o, c.)$$

The expression for the grain at the center will be, then, like Eq. 3.

PLATE VI.

Typical ophitic drill cores. Photographic plate after Annual Report for 1904, Plate XVII.

The cores are arranged with that nearest the bottom at the extreme left, as follows: 20620, 20619, 20618, 20617. Depth in drill hole 250, 232, 202 and 172 feet. Distance from margin at 257 feet, 4, 13, 28, 43. Apparent grain 0.5 to 1, 1 to 2, 2 to 3, 3 to 4 mm. Thin sections 1.5 to .74, 2 to 1.34, 3 to 2.8, 4.5 mm. 20618 analyzed.



250 232 202 172

APPROXIMATE DISTANCE FROM MARGIN, IN FEET:

4 13 28 43

LUSTER-MOTTLING IN DRILL CORES OF OPHITES

If the cooling has gone on so far that there is a belt of constant grain at the middle ($m_o < 2.5$ practically) then by Eq. (8).

$$(12)\quad g\left(k, x = \frac{c}{2} \text{ or } x' = w,\ u,\ u_o,\ y,\ c\right) = E = \frac{ck}{a\sqrt{u_o}\,\pi\,\sqrt{u/u_o}} = \frac{ck}{a\pi\sqrt{u}}$$

The grain does not depend on the initial temperature, only on the difference between the temperature of crystallization and that of the country rock, being greater the less this is.

At the Margin.

(Consolidation temperature nearer that of country rock.)

Here.

(13) $v = \frac{1}{2} u_{2y}$ whence we find that the grain at margin, if $u < u_o/2$ is,

(14) $g(k, x = y, v, u_o, y, c) = \sqrt{2}\, g(k, 2y, 2v, u_o, o, c)$.

If u/u_o is so low that this value falls in the second period, i. e., $m_o < 2.5$, and the grain is that of the belt of central grain as in (12)

$$(15)\quad g(k,\ x' = y,\ v, u_o,\ y,\ c) = \frac{kc}{a\sqrt{u_o}} \cdot \frac{1}{\pi\sqrt{v/u_o}}$$

Comparing equation (14) and (15) with (11) and (12) we infer that if the temperature of consolidation is low enough the grain may be the same from center to margin. Otherwise it may be shown to be coarser at the margin if $u < u_o/2$.

(Consolidation temperature nearer that of injection.)

Inasmuch as $v = 1/2\, u_{2y}$ at the margin, so long as u_{2y} has not dropped from u_o, v will be equal to $u_o/2$. During this time the cooling will be as though the temperature at the margin were fixed at 0. It will be the same as that of a sheet of constant marginal temperature (which is taken as 0) of which the initial temperature will be $u_o/2$ and u will be $v - \frac{u_o}{2}$. The expression of grain in terms of the ratio u/u_o we must change accordingly.

(16) $g(k, x = x' + y, v, u_o, y, c) = g\left(k, x', v - \frac{u_o}{2}, \frac{u_o}{2} 0, 2w\right)$, where $2w = c - 2y$ and going back to equations (5) and (6) we find

$$(17)\quad g = \frac{k}{a\sqrt{u_o}}\ \frac{x'}{h'}\ \frac{\sqrt{2}}{\sqrt{2\left(\frac{2u}{v_o} - 1\right)^2}} = C'x'$$

Where h′ stands in the same relation to $\frac{x'}{2w} \cdot \frac{2v}{u_o} - 1$ as h to $\frac{x}{c}$ and $\frac{u}{u_o}$, i.e., h′ is for points close to the margin crystallized in early times independent of $\frac{x'}{2w}$, (this will be true for the linear rate of increase of grain at the margin) and while it depends on $\frac{2v}{u_o} - 1$ it will vary only between .7 and .87 if $\frac{2v}{u_o} - 1$ is less than .966, i. e., $\frac{v}{u_o}$ is $< .983$. That is unless the crystallization is practically coincident with the consolidation h′ is roughly constant, until the center has cooled appreciably.

$$(18)\quad h' = \sqrt{\frac{-d\,\frac{x'}{2a\sqrt{t}}}{d\left(\frac{2v}{u_o}-1\right)}\left(\frac{\frac{2v}{u_o}-1}{\frac{x'}{2a\sqrt{t}}}\right)^3}$$

$$= \frac{2w}{x'}\,(M_o)\,\sqrt{\frac{\left(\frac{2v}{u_o}-1\right)^3}{d\,\frac{2v}{u_o}-1}}$$

in which t as a function of $\frac{x'}{2w}$ and $\frac{2v}{u_o} - 1$ and $M_o = \left(\frac{a}{2w}\sqrt{dt}\right)$ must be taken from a table like Table I, Report for 1903, using $\frac{x'}{2w}$ for the distance, $\frac{2v}{u_o} - 1$ for the temperature.

Intermediate Zone.

The curve of cooling of the extreme margin thus indicated may become practically coincident with a curve of cooling of a sheet of reference with width c and fixed marginal temperature of 0. If that is so,

$$(19)\quad v = \tfrac{1}{2}\,u_{2y} = u_{y'}$$

when 2y represents the distance from the margin of the point whose cooling is represented by the curve of cooling of the sheet of reference (Figure 20), with constant temperature at margin, with which the curve of cooling of the margin becomes coincident. If the cooling has gone so far that it can be represented by the first term of Eq. (2) we can see that Eq. (19) can be true and that

$$(20)\quad \frac{\pi}{4}\,\frac{v}{u_o} = \frac{1q}{2}\sin\frac{\pi\,2y}{c} = q\sin\frac{\pi\,y'}{c}$$

gives us a simple trigometric equation to solve to find y'

$$(21)\quad \frac{\pi\,y'}{c} = \sin^{-1}\tfrac{1}{2}\sin\pi\,\frac{2y}{c}.$$

But we also see that if y is so small, that is, the contact zone so small, that sin 2 π y' / c is proportional to 2 π y / c then y' will be the same proportional to y, and more generally, if it is so small that sin n π y / c is proportional to n π y / c, to the number of terms of Eq. (2) covered by n will y' be proportional to y and eq (19) be true. Not only that, but in equation (1) if $v/u_o = P_{\frac{y'}{2a\sqrt{t}}}$, and if $P_{\frac{2y'}{2a\sqrt{t}}}$ is nearly proportional to $\frac{y'}{2a\sqrt{t}}$ which it is if $\frac{v}{u_o} < .33$, then to the same extent will:

$$(22)\quad \frac{v}{u_o} = \tfrac{1}{2}\,\frac{u_{2y}}{u^o} = \tfrac{1}{2}\,(\text{constant}\times)\,\frac{2y}{2a\sqrt{t}}$$

$$= (\text{constant}\times)\,\frac{y'}{2a\sqrt{t}}$$

and $v = u_y$

That is to say if the contact zone y is small enough so that 2 $v = u_{2y}$ becomes 0.33 u_o before the center has cooled perceptibly, or the marginal temperature becomes say 1 / 6 of the initial, the cooling at that margin will be the same as at a corresponding point of the sheet of reference whose walls are kept cold. At the same

time the cooling at the center is the same as that of another point in the reference sheet, at a distance $\frac{c}{2} - y$ from the wall. The cooling on two planes, center and margin being the same as on two planes of the reference sheet, the cooling between must be the same, except that due allowance must be made for the different distance apart of the two sets of planes. The distance of corresponding planes being thus proportional we obtain a formula:

$$(23) \quad g\,(k, x, v, u_o, y, c,) = g\,\left(k, \frac{c-2y+y'}{c-2y}\, x' + y', u, u_o, 0, c\right) = A\,x' + B$$

if $2 \sin y\,\pi\,c = \sin 2\,y\,\pi\,c$ nearly.

At the center (23) reduces to formula (11) and writing $g = Ax' + B$ and the expression $(k\ c/a\sqrt{u_o})$ K comparing it with Eq. (3), and (5) we find

$$(24) \quad A = \frac{K}{c}\,\frac{c\text{-}2y\text{-}2y'}{c\text{-}2y}.\,\frac{1}{h\sqrt{2}\,(u\,/\,u_o)^{3}}$$

$$(25) \quad B = K\,\frac{y'}{c}\cdot\frac{1}{h\,\sqrt{2}\,(u\,/\,u_o)^{3}}$$

The equation (23) is the equation of another tangent to the curve of grain if we consider A and B constant. It will appear in the case of small contact zones at a point of minimum curvature.

It is of importance as the rate of increase A is most characteristic of the Keweenawan flows. It becomes more and more important, and represents more and more of the curve of grain, the less the contact zones are and the more immediate the crystallization.

It may be distinguished from the other tangent to the curve of grain by the fact that it does not give a 0 grain at the margin. We notice, too, that

$$(26) \quad \frac{B}{A} = y'.\,\frac{c\text{-}2y}{c\text{-}2y\text{-}2y'} = y'\,\frac{2w}{2w\text{-}2y'} = y'.\,\frac{w}{w\text{-}y'}$$

This is always positive unless $y + y' > 1/2$, i. e., unless the contact zone is greater than the width of the dike $> c/4$ on each side, and is for small contact zones practically proportional to the contact zone.

If a series of observations of grain give a value of B negative or very small it is pretty likely that they refer to the equation $y = C'\,x'$ and that the value of B is due to the errors of observation.

Approximate Formulae.

If we make certain simplifications, which can generally be done without appreciable loss of accuracy, we can obtain formulae not bad to handle numerically.

Assume that y is equal to y′ and that the fraction $\frac{c\text{-}(2y+y')}{c\text{-}2y} = 1$. This we may do when the contact zone is relatively small. We will also introduce h′ as before and call $v/u_o = f^2$ and we have the following formulæ:

(27). $C' = K/\,ch'\,(2v/u_o - 1)^{3/2} = K/ch'\,(2f^2 - 1)^{3/2}$. As $K/c = k/a\sqrt{u_o}$, C′ is independent of the size of the dike or the contact zone, and is the marginal rate of increase.

(28) $A = K/\,ch(v/u_o)^{3/2}\sqrt{2} = K\,/\,chf^3\sqrt{2}$, from (24).

(29) $B = Ky'/\,ch(v/\,u_o)^{3/2}\sqrt{2} = Ky'/\,chf^3\sqrt{2}$, from (25).

(30) $E = K/\,\pi\sqrt{v/u_o} = K/\pi\,f$, and is independent of initial temperature.

From (28) and (29) we can determine y', the effective contact zone, which is B/A.

(31) $y' = \frac{B}{A}$.

If y comes out less than 1/12 of c, we may be sure that so far as the contact zone is concerned our approximate solutions are close. From (28) and (30) we can find c in the terms of A, E and K—that is, we can sometimes by observation of the grain determine the thickness of the dike before it was completely penetrated if from a general knowledge, or from Eq. 30 we could infer f. Moreover, we can find f in the terms of A, E and c, and if f^2 does not come too near to unity we may feel that our approximate formulæ and results from them are not likely to be far out. We can also find K in the terms of A, E and c, or if we have also Eq. (27) we can either check on our observations or get along without c or some other factor. From formulæ (27) and (28) we can find f in the terms of C' and A, although the equation is a cubic. It is quite rapidly solved by approximation. We can then find K/c.

Then let a certain observed rate of increase of grain, represented by the slope of a certain straight line tangent to the curve of grain be s. We may not know whether it represents C or A as we have said. We shall have either $f^2 = u/u_0 = E/.45$ hsc — from equations (30) and (28) letting s = A; or from equations (30) and (27) letting s = C'

(32) $2f^2 = 1 + (E/.45\ h'sc)^{\frac{2}{3}}\ (2f^2)^{\frac{1}{3}}$. This equation is solved approximately in Figure 21. Thus it will be comparatively easy to obtain the alternative values of v/u_0 on the two hypotheses. Since $2v/u_0$ is always between 1 and 2 and the cube root varies but slowly, it will be easy to insert an approximate value in (46) and obtain nearer approximations. Moreover having found v/u_0 we can go on to find K.

(33) $K = \pi E f = \pi E \sqrt{\frac{u}{u_0}} = Cch'\ (2f^2 - 1)^{\frac{3}{2}} = Ach\ f^3 \sqrt{2}.$

In formulae 24 and 28, in the expression for A, as v approaches u_0, h will approach zero and so the expression for A might become infinite. That would imply that the nearer the initial temperature is to the temperature of a consolidation the greater will the gradient A become but of course this is limited by the fact that at a temperature very close to that of a consolidation the lava flow would be so viscous as no more to flow. The temperature above the consolidation point at which the magma becomes sharply fluid is very much less for magmas and glasses containing lime than for those which contain soda and therefore a coarser and better marked rate of increase and a more distinct development of the A gradient is noted in the lime melaphyres. At the same time there is distinct signs of a limit here, and the A gradient is, so far as I know, never over one millimetre in seven feet. From this we can draw an inference regarding the temperature at which a lava is fluid enough to flow compared with that of the formation of augite.

An interesting question is where the various tangents meet—that is, where will the zone of marginal grain become equal to that of the center. If we refer to the equations of the three tangents we have the following formulæ:

(34) $x'_{13} = E / C' = ch'\ (2f^2 - 1)^{\frac{3}{2}} / \pi f$,

where x'_{13} is the abcissa of the meeting point of tangents representing the rate of increase of grain at the extreme margin C', and that at the center.

The solution of this approximate formula as well as (in dots) curves representing more accurately the actual relation for three different breadths of contact in terms of $x'_{13} / c = E / C'c$ is given by the full line of Figure 21 (Fig. 6 of the annual report for 1903) repeated here for these values.

u/v_o......	.84	.80	.76	.71	.66	.61	.56	.50
$E/c'c$.....	.168	.145	.121	.093	.067	.038	.014	0

If instead of expressing the ratio of superfusion as a function of the marginal rate of increase C′ the grain at the center E and the total width affected it be expressed in terms of the distance from margin W we may roughly express the relations in words by saying that E, the grain at the center, is less than that which would be found if the increase at the margin, kept up proportionately to the superfusion, and the drop from the initial temperature to that of crystallization is to the initial temperature (reckoned from that of the country rock as zero), as the thickness of the central belt in which the coarseness would be about as much as at the center is to (somewhere between once and twice) the total thickness.

$$(35) \quad \frac{u_o - u}{u_o} = \frac{2w - 2\,E/C'}{2w(\times 1 \text{ or } 2)}$$

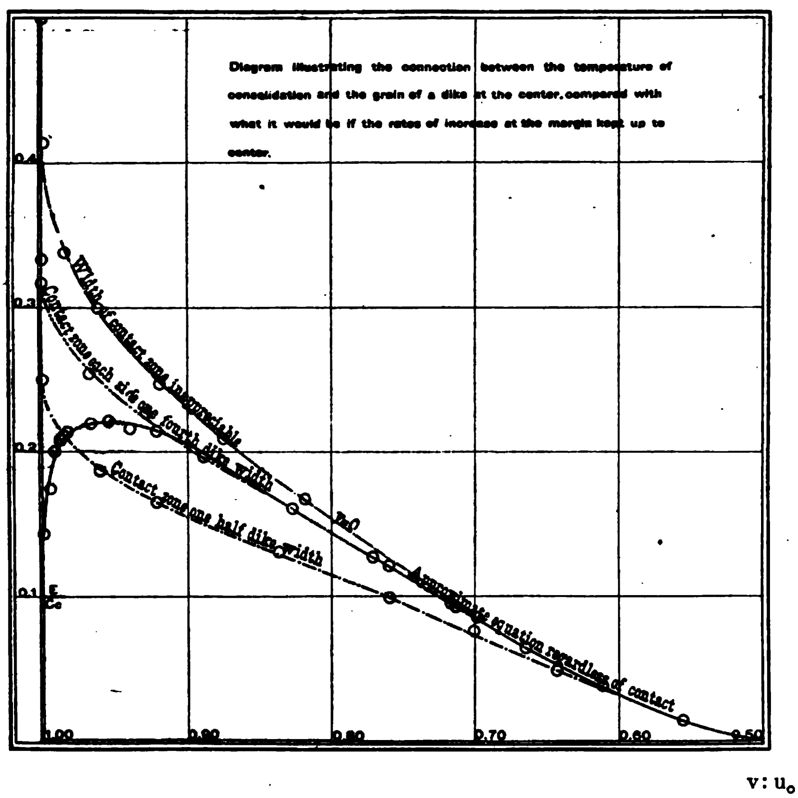


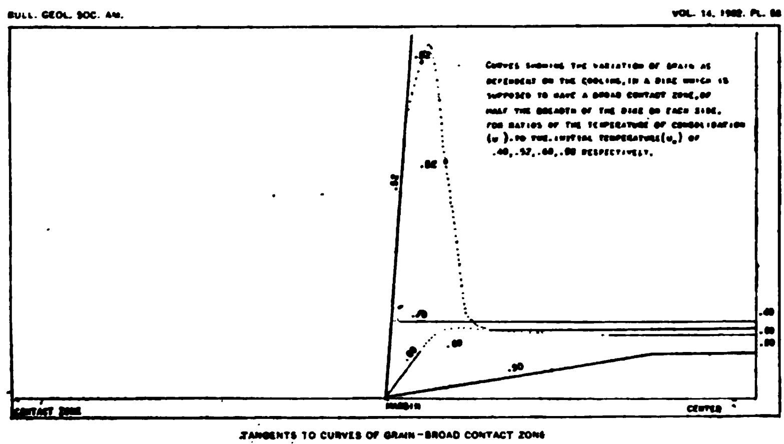
Fig. 21. S shows $E/C'c$, or the ratio of the grain at the center to that which would be reached if the rate of increase at the margin kept up for a distance equivalent to the whole zone affected. The full curve is the approximate solution given by equation 34 of the text. The dotted curves were computed for particular widths of the contact zone as shown thereon.

Similarly

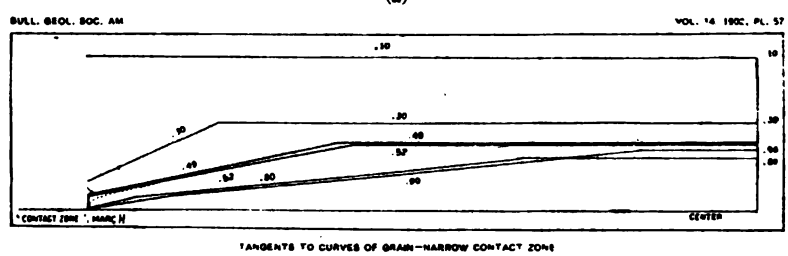
$$(36)\quad x'_{23} = (E-B)/A = .45\ hcf^2 - y',$$

where $(x'_{23}+y')/c$ is less than .4; and finally equations (27), (28), and (29) will determine a point

$$(37)\quad x'_{12} = B/(C'-A) = y \Big/ \frac{h}{2h'}\left(1-\frac{1}{2f^2}\right)^{-\frac{1}{2}} - 1.$$



(a)



(b)

Fig. 22. Illustrates the variation of coarseness of grain from the margin to the left to the center at the right in flows, intrusive dikes or sills which have either: (a) a broad contact zone; or (b) a narrow contact zone in which the contact zone heats up and cools down quickly. The curves are dotted in. Important tangents to them are drawn in full lines. The decimal figures adjacent to each curve indicate the ratio of the temperature of consolidation to that of initial injection or intrusion, the temperature of the country rock being taken at zero.

From formulæ (35) and (36) we shall not be able to find the width of the contact zone, but we may if we know over what range some of these formulæ are closely applicable. If, for instance, formula (27) holds at least to a value x′, it may be shown that

$$2y \text{ is not less than } x'/P^{-1}\,[2(u/u_0)-1 \text{ or } 2w]$$

Also in equation (37), if we know exactly x'_{12}

$$(38)\quad y = \left(\frac{(2 \text{ to } \infty)^{\frac{1}{2}}\,h}{2h'} - 1\right)x'_{12} \quad = \left(1.4 \text{ to } \infty\ \frac{h}{h'} - 1\right)x'_{12}$$

C′ must always be greater than A and between C′ and A there is the relation

$$(39)\quad \frac{C'}{A} = \left(\frac{h\sqrt{2}\,(2-1/f^2)^{\frac{1}{2}}}{h'}\right)\left(\frac{C-2y}{c-2y-2y'}\right)$$

up to values of $f^2 = u/u_0$ of about .80 $\frac{h}{h'}$ is nearly 1 but as u/u_0 gets above .90 it rapidly diminishes but does not fall below $\frac{1}{\sqrt{2}}$. Thus for small contact zones

$$(40)\quad \frac{C'}{A} = \frac{\sqrt{2}}{1 \text{ to } \sqrt{2}}\left(2-\frac{1}{f^2}\right)^{-\frac{1}{2}}.$$

Again as $c - 2y = 2w$ we find $\frac{c-2y}{c-2y-2y'} = \frac{2w}{2w-2y'} = \frac{w}{w-y} = 1 \Big/ \left(1-\frac{y'}{w}\right) y'$ so that if $y' = w\ \frac{C'}{A} \doteq \infty$

Some of the tangents just described are shown in Fig. 22.

§ 7. APPLICATIONS.

If the initial temperature and diffusivity of igneous magma are not dependent on the position and time, whatever crystallization takes place at the margin before the center or margin has cooled appreciably follows the law that the coarseness of grain is proportional to the distance from the margin (the margin not varying in temperature either because kept at a constant temperature or, if it is the country rock, because it has not departed much from it, at a temperature half-way between the initial magma and country rock temperature).

On the other hand the crystallization that takes place after the center has cooled down considerably should be uniform in grain or not less than that at the center.

This belt of uniform grain will occur, if at all, near the center and, as we have said, the greater its width the nearer to the crystallization temperature must the marginal temperature have been. In this belt the size of the grain may not depend on the initial temperature at all but besides being proportional to the size of the dike and the power of crystallization, and inversely proportional to the square root of the diffusivity, will be the greater the less the difference between the crystallization temperature and the temperature of the country rock down to which cooling is taking place.

If the temperature or other conditions of crystallization are nearer those of the country rock than those of the magma, there may be no marginal zone of finer grain.

There may be a belt of coarser grain than that at the center. It should be at the margin if the initial marginal temperature is just above that of consolidation. The higher the temperature of

consolidation the farther in and less defined the belt must be if present at all. To be at all appreciable it must be close to the contact. It is produced as the contact zone approaches the maximum temperature it attains. The fact that the grain of a rock may be coarser at the margin than at the center, considering loss of heat alone as a factor in crystallization, is not easy to see at first glance. It means that the margin cools more slowly *not at the same time*, for of course it cools first, but at or through the same range of temperatures. This may be made more clear by looking at a figure of cooling with a broad contact zone (Fig. 18). We see that the curve of cooling at the margin takes about half a year to drop .1 in temperature, from .5 to .4 of the initial temperature, while the center, when it gets down to the same range, passes through it in not much more than a quarter year. We may make this slower cooling at a given temperature at the margin seem more reasonable by the following considerations.

The rapidity of cooling depends among other things on the amount of drop to be made. Now at the beginning the contact country rock is cool, the drop marked, and the cooling rapid; accordingly, for that part of the dike that cools and crystallizes during that time, the grain is fine. But as the country rock heats up, while it is heating up the interval down to which the dike of molten rock must cool is growing less and so the crystallization is very much slower, the grain much coarser than were the contact zone kept at a fixed temperature. Later the contact zone cools too, with the dike as a whole. Now while the contact zone is heating up and the dike cooling down the parts at the contact are held at a temperature just about half way between the initial temperature of the dike and the country rock. Thus the conditions are favorable for very slow crystallization in the part of the dike then crystallizing.

A uniform grain throughout like some of the dikes in the Mt. Bohemia oligoclase gabbro may then indicate one of three conditions. (1) An excessively hot magma. I have not seen any yet which seemed to me attributable to this cause. (2) The retention of some mineralizer which makes the crystallization point relatively low. This condition may hold not only in veins but in many aplitic and pegmatitic dikes. (3) The fact that the country rock itself was relatively near the fusion (respectively solution) point, as in the case of dikes injected into granites or gabbros which have only just consolidated.

Effusive rocks generally have broader marginal zones of grain

increase than intrusives for (1) the magma is likely to be less hot, in fact to flow and keep stirred up until it stiffens near the crystallization point. (2) Loss of mineralizers is likely to raise the crystallization point. (3) The country rock is relatively cool and if wet will absorb a large amount of heat, making the thermal contact zone narrow. Marginal belts of coarser grain I have never observed.

As a matter of fact most of the Keweenawan ophitic melaphyres do show an increase of grain, especially of augite, from the margin to the center. The rate of increase, however, is not strictly proportional to the distance from the margin except for a short distance near the same. There is a narrow contact zone of a meter or less which heated up first, and a zone of corresponding width inside the dike in which the grain of the augite increases quite rapidly and proportionally to the distance from the margin (at the rate C′). Then later the contact zone and all cooled and for the part then consolidated the grain increase changes to a smaller rate (A) which is more nearly proportional to the distance from a point outside the exterior of the contact zone.

But the rapid marginal rate of increase is usually confined to the first few feet, and can be determined only by careful microscopic work. The rate of increase is, on the whole, more uniform in the lower part of each flow than the upper, where the amygdules and probably original eddies in the flow introduce uncertain factors.

My original empirical rule for the second rate of increase (A) was that in the commonest type of Keweenawan flow, the ophitic melaphyre with about 10 per cent of CaO composed of about 55 per cent labradorite and 30 per cent augite, the grain of the augite in millimetres was, allowing a margin of 1 mm. each way, equal to 6 per cent of the distance in feet from a point 20 feet outside the margin, or at the rate of 1 inch in 400 feet (1 mm. in 16 feet). More scientifically expressed the ratio is 1:4800 or .00021.

Further investigations indicate that the main rate (A) may be somewhat higher, up to .00046 (1 mm. in 8 feet) without being marginal. It must not be forgotten that this formula from eye observation is rough, covering really two different theoretical gradients.

However, the errors in measuring grain are of the same order, and there are also errors which come in from unequal original temperature and variation in composition, such as produce the variation from ophitic to doleritic texture.

PRACTICAL APPLICATIONS OF OBSERVATIONS OF AUGITE GRAIN IN OPHITES.

1. Amygdaloid inclusions, bombs, or streaks and doleritic streaks in the body of a flow may be distinguished from the main amygdaloid top by the more regular and persistent diminution of grain toward the latter.

2. The extra coarse flows are extra thick and extra persistent and may be identified by the maximum grain. For instance, the "Greenstone" just above the Allouez conglomerate extends from Keweenaw Point to Isle Royale and down the point to Portage Lake, though it thins in this latter direction. The augite mottles are as large as 3 inches across where it is thick. The Mabb ophite with a grain of over 7 mm. comes shortly above the Baltic lode. One may thus identify a flow as a unit.

3. One may, from an extra slow increase of grain in diamond drill holes, infer that the bed is being traversed obliquely. One must have due regard to the possibility of being deceived by a different rate of increase of grain due to some other cause,—different chemical composition, for instance.

But if the same bed is cut by different holes traversing it at different angles[5] one can often feel fairly safe. For instance, Hole 5 at the Challenge exploration (Chapter V, § 18) was put down through a heavy glacial overburden 143 feet where little or nothing was known as to the dip. The slow increase of ophitic mottling in the bed from 143 to 257 feet led Dr. Hubbard quite correctly to infer that it was traversed quite obliquely and had a dip of 60° or more. (See Pl. XVII, report for 1904, Pl. VI, and Fig. 59 of this report). Another illustration is Empire section, Figure 24, Hole 5, Belt 51.

4. If a variation in grain can be noted on two sides of a shaft, a cross-cut, or an outcrop, the direction of finer grain is probably that of the nearer amygdaloid or conglomerate, and the coarseness of grain will indicate the probable distance.

This is of especial use in a drift covered country where it is often impossible to sink exactly on the amygdaloid ashbed. This principle was used in fixing the position of the Allouez in the Empire section. (Fig. 24.)

Good illustrations of the importance of grain in determining dip will also be found in the southern part of the Mandan section, where I was led to infer a steep dip from observations in vertical holes before it was otherwise proved.

5. A sudden variation in grain in crossing a seam may indicate a displacement and guide one in determining its character and amount. (Cf. the Isle Royale section, drill hole 10 and the Challenge exploration.)

[5]See Bed 32 of the Clark-Montreal section.

6. It will often be possible to tell how far there is yet to go to traverse a bed after it has been more than half penetrated, for it will begin to get finer again.

In this way it was possible to say that a Calumet and Hecla drill hole near Shaft 21 which was stopped by an accident was just about 30 feet from its goal.

7. A uniformity and system in grain may distinguish small outcrops from large boulders. This principle and principle 4 were also made use of near Shaft 21, Calumet and Hecla, where there were some dubious outcrops of the hanging of the Kearsarge lode.

8. Conversely, a very coarse grain indicates a very heavy bed of trap, and thus gaps in a geological section may be filled. It does not, for instance, require continuous trenching or exposure by drilling over the Greenstone to make sure of not missing amygdaloids.

9. Large masses (30 feet or more) of aphanitic (porcellanic) rocks, if igneous, are likely to be felsitic.

10. Intrusives are often characterized by extra coarse feldspar, and relatively narrow marginal bands of finer grain near the margin.

11. Beds without variation of texture (or actually coarser) at or near the margin are intrusive.

CHAPTER V.

DETAILED STRATIGRAPHY.

§ 1. INTRODUCTION.

A general summary of the Geological Column of the Keweenawan is given in Chapter I, § 7, and in the Report for 1908, pages 30 to 38. The column or succession of beds is illustrated by Figure 4 in this chapter. We may proceed at once to consider the detailed sections. In Chapter I we took up the order of succession first with the Lower Keweenawan and the lower part thereof,—the Bohemian Range Group. It seems to me best in this chapter to follow a geographic order, and begin at the end of Keweenaw Point and go thence westerly in general with the hands of the clock and with the sun around Lake Superior, since the sections explored in the different regions vary and overlap the different divisions more or less. It may be well, however, to run briefly over the different divisions and indicate in what regions they occur.

The Lower division, the Bohemian Range group with conglomerates and felsites at its top, extends from the part so carefully studied by Hubbard on the south side of Keweenaw Point near the mouth of the Montreal River, T. 58, R. 38, past the Mendota section (Fig. 26) almost all along the range, though often heavily masked by drift. The Torch Lake section shows but very little of it and it may be that where the Keweenawan fault uplift is much split it is absent altogether. The South Trap Range coming around from the south end of Lake Gogebic, and lying south of the Duluth South Shore and Atlantic Railroad seems to be wholly in this group. I judge that it is developed in Wisconsin and Minnesota, but does not appear on Isle Royale. I think that the Mamainse section is largely in this group.

The Central group is that found everywhere. Most of the sections are in it. (Fig. 24 et seq.)

The Ashbed group is very continuous, yet little drilling has been done in it outside of Keweenaw County. South of Atlantic the only drill section exposing it well is that at the Winona. Apparently from the Ontonagon County line toward the Porcupine Mountains it contains genuine felsites which are absent elsewhere. I do

not think that the Mamainse felsites are of this age, but rather earlier. There seem to be, really, but two epochs of felsitic intrusion. The only sections that show it well are those at Copper Falls (Fig. 30), Eagle River (Fig. 34), Calumet and Tamarack (Fig. 36) and Isle Royale (Fig. 56). The Arcadian (Figs. 41 and 42) and Winona (Fig. 50) shows something of it and it is exposed around Rockland (Fig. 52).

Structurally, the Upper Keweenawan might begin here, but it has been defined as not including any effusives. So defined, the "Outer" or uppermost of the Copper Harbor conglomerates becomes its base, and the Upper Keweenawan fringes the north side of Keweenaw Point from less than half a mile from the end to the north branch of Agate Harbor (broken by Copper Harbor), reappears about five miles west of Eagle River and about one mile northeast of Gratiot River and occupies the coast up to Oronto Bay. (See Report for 1908, Fig. 3.) Its upper member, the Freda sandstone, is frequently exposed, but only where uplifted by the Porcupine Mt. faulted anticlinal (see Annual Report for 1908, Pl. 1) are the lower members exposed along shore, and in the interior where there are numerous exposures which may be attributed to the Copper Harbor conglomerates, the Lake Shore traps are rarely found. They, indeed, seem to be absent for part of the way between Portage Lake and the Porcupines, where the base of the Upper Keweenawan has not been accurately located. Above the Lake Shore traps there are really no signs of igneous activity. That is one reason for my belief that the Upper Keweenawan is closely allied with the overlying Upper Cambrian Lake Superior Sandstone. This agrees with Irving's general statement,[1] although in describing the Porcupines he mentions (p. 223) a heavy dike of olivine diabase on Section 26-51-44 which, if it occurred, would be an exception to this rule. But at the point indicated there is only the emergence of a great fault with gritty beds of the Nonesuch indurated so as to look exceedingly like an igneous rock,—from a boat, for instance. Since the original notes and specimens have been lost one cannot say how the mistake occurred. Probably[2] Irving did not visit this place himself.

The Eagle River group probably interdigitates with the Great Copper Harbor conglomerate by the dropping out of its upper trap beds. The Copper Falls (Fig. 30), Eagle River (Fig. 34), Calumet (Fig. 36), the workings of the Hancock mine, the Black River section (Report for 1906, Pl. 33) are the best sections.

[1]Monograph V, U. S. G. S., p. 152.
[2]Loc. cit., pp. 3 and 4.

The Copper Falls conglomerates, Great, Middle and Outer, and Lake Shore traps have been but little explored and few of the diamond drill sections indicate them. They are best exposed in the Porcupine Mountain district. The heaviness of these conglomerates and the variety of pebbles they contain indicate to me a very considerable unconformity.

§ 2. END OF KEWEENAW POINT. CLARK-MONTREAL (FIG. 23).

On the end of the Point the beds run fairly continuously from west to east, tending southeast at the tip, though traversed by veins nearly at right angles to them, with which are associated faults nearly at right angles to the formation with small throw. These faults, on the whole, strike more northeasterly than they would were they just at right angles to the strike and the east side is often thrown south. (See Keystone Location 30, T. 57 N., R. 27 W.). The explorations seem to have been almost exclusively confined to the veins and to the horizon just below the Greenstone, the Allouez.

The beds are best shown at the end of the Point (where the dip is about 23°), and opposite Copper Harbor, where the upper beds were described in the very earliest report[3] and again by Irving[4] and Hubbard.[5]

We have the following section according to Hubbard (p. 63 and Pl. IV) assuming the Greenstone to be 1,270 feet thick, (its breadth of outcrop of about half a mile combined with a dip of 31° to 35° and its thickness in the Mandan section all point to a thickness of over 1,000 feet).

Outer conglomerate	(1000 feet[6])	(half a mile of 23° dip)
Upper Lake Shore Traps	(1062 to 1100)	
Middle conglomerate	(200 to 700)	
Lower Lake Shore Traps	(400 to 550)	
Great conglomerate	(1200 to 1250)	
Eagle River group	(1308)	(Irving 1,417)
Ashbed	(2000)	(Irving 1543)
		3270?
Greenstone?	(1270)	(Irving 1200)

Some drilling above the Greenstone up here would be desirable, though the flat dips are against easy mining. From the foot of the

[3]See Foster and Whitney.
[4]Monograph V, U. S. G. S., pp. 186-187.
[5]Vol. VI, Pt. II, Chapter II and Chapter III. §§ 8 and 9.
[6]Thicknesses in parentheses, (25) for instance, refer always to true thickness at right angles to the dip.

Greenstone to the north shore of Breakfast Lake a section was drilled by the Calumet and Hecla Mining Company, whom I have to thank heartily for permission to examine the cores and especially for the results of the cyanide tests for copper. The detailed section follows, and is illustrated by Figure 23.

Calumet and Hecla section on Clark property N. from Breakfast Lake ¼ mile west of the East line of Sections 8 and 5, T. 58 N. R. 28 W. See Figure 23 (In envelope).

Sections by W. J. Penhallegon, and notes of A. C. Lane.

The section gave an average tenor of copper as follows

Hole 1.	943 ft.	into	5.1199[a]	ave.		.C05	copper
2.	597	"	"	1.185	"	.00196	"
3.	445	"	"	3.01	"	.00675	"
4.	432	"	"	2.032	"	.0047	"
5.	424	"	"	4.385	"	.0106	"
6.	581	"	"	47.037	"	.077	"
A.	236	"	"	2.62	"	.011	"
7.	360	"	"	5.425	"	.015	"
8.	641	"	"	18.12	"	.0285	"
9.	378	"	"	15.655	"	.0415	"
	5,037			104.5889	ave.	.02	

But there was a certain amount of duplication and overlapping which should be allowed for as it materially affects the results. On the other hand, nothing less than .01% was estimated, so that an average of .0025 may easily have been ignored.

Closer figures could be obtained by taking the content for each bed, and multiplying by the thickness, did it vary with different beds and remain constantly high for some, but it does not. The average is not very different from that obtained in Holes 1 and 2 at Mamainse. Unless mentioned the sludge is reported as .00 copper. On the whole there is more copper in the upper beds. The distribution seems rather associated with chlorite seams than bedded lodes.

Clark drill hole 9. On the "Greenstone" 5739 feet north of Breakfast Lake and 106.84 feet above it (288.01 above Lake Superior) about 1250 paces N., 500 W. in Section 8, T. 58 N., R. 28 W. The dip of the hole is 66° 30′ to the south, i. e., so nearly at right angles to the beds that true thickness is obtained at once, though the dip appears to be really about 26°.

1. Ophite, the Greenstone d 9. 12-34 (72)

   An ophite growing finer at 24-30; 0.09 copper

2. Conglomerate, the Allouez No. 15 d 9. 34-82 (48)

   It is basic especially below 76 and there are pebbles of ophite as well as felsite. It is mainly fine grained. The dip varies from being at right angles to the drill core about 6° to 7° indicating a possibility of a dip just that much more or less than 23° 30′; at 31-37 the copper content is 0.07, 37-43, 0.19, at 43-62, 0.03, at 64-82, 0.07.

3. Feldspathic melaphyre (46)

   Amygdaloid d 9. 82-87 = (5) at 82-83, 0.06, at 83-85, 0.07 Cu

   Amygdaloidal trap d 9. 87-91 = (4), at 85-99, 0.05 Cu.

   Feldspathic trap d 9. 91-128 = (37), at 99-102, 0.05, 102-107, 0.09. at 107-117, 0.59, 117-120, 0.71, at 120-122 0.64 Cu.

[a]Total obtained by multiplying the percentage of copper in various samples by the number of feet which the sample represented.

4. Melaphyre (17)
Amygdaloid d 9. 128-130 (2), at 122-130, .08 Cu.
Amygdaloid trap d 9. 130-145 (14); at 130-153 trace Cu.
The trap is coarse amygdaloidal except the last foot at 145.
5. (8)
Amygdaloid d 9. 145-150
Chloritic amygdaloidal trap d 9. 150-153 = 3
6. Amygdaloid d 9. 153-154 = 1, 153-154 0.03 Cu. (8)
Coarse amygdaloidal trap d 9. 154-161 = 7 (79)

7. (59)
Amygdaloid d 9. 161-166 = 5
Amygdaloidal trap d 9. 166-173 = 7
Trap d 9. 173-220 = 47
Coarsest between 177 and 206, chloritic and white flecked with pseudoamygdaloid spots at 175-184, trace Cu.
8. Top of Mandan ophite? 138
Ophite 8 mm? (101?)
Amygdaloid d 9. 220-223 = 3
Amygdaloidal trap d 9. 223-228 = 5
Trap d 9. 228-271 = 43
Amygdaloid d 9. 271-273 = 2
Trap d 9. 273-321 = 48
The amygdaloidal trap is a very coarse amygdaloid, the first trap feldspathic and faintly mottled, at 255-273 and 363-375, trace Cu.
The second two feet of amygdaloid is a poor chloritic amygdaloid with forms that look like pseudomorphs of phenocrysts. At 284 it is coarser and irregular and from 305-312 there appears to be a mottling 5-8 mm. across. This is about the point where the big Mandan ophite should appear. What has become of the rest of it? Is it cut out by faults?
9. Melaphyre (34)
Amygdaloid d 9. 321-323 = 2
Trap d 9. 323-355 = 32
The amygdaloid is chloritic.
10. Melaphyre
Amygdaloid d 9. 358-360 = 2
Trap d 9. 360-368 = 8
The amygdaloid is crushed; the contact uncertain.
Porphyritic melaphyre
Amygdaloid d 9. 368-375 = 7
Amygdaloidal trap d 9. 375-390 = 15
The trap is a coarse, chloritic amygdaloid and shows one big porphyritic feldspar crystal. Clark d 8. 260-304, also Clark d 8. 304-401. This does not look like the top of No. 8 particularly. I strongly suspect a fault. The mottling at 305-312 feet is not at all likely in so small a flow and I think that the lower amygdaloids may be streaks in the trap, for the samples when examined were mouldy and not easy to study.

Clark drill hole 8. 642 feet south of No. 9, i. e., 5097 feet north of Breakfast Lake and 44.75 above it (225.92 above Lake Superior); about 1025 paces N. and 500 W. of S. E. cor. of Section 8, T. 58 N. R. 28 W. The dip of the hole is 65°, i. e. practically at right angles to the bed. The dip to Hole 9 may be 26°, to Hole 7 26.5°. It is physically 62 feet below No. 9 and geologically should be between

300 and 400 feet below. The big ophite in which it begins would seem to be the Mandan ophite, which comes usually not over 300 feet or so below the Greenstone. If we assume this to be the last bed reached in No. 9 there must be an unusual number of beds between this and the Allouez, and a dip of over 33°. If, on the other hand, we suppose the apparently coarse mottling reached at No. 9 at 305-312 feet to represent the Mandan ophite and cf. d 9. 305-312 with d 8. 75-91, the dip would be only about 20.3° and we should have to suppose also that Hole 9 crossed a fault in its lower part striking N. E. and throwing the E. part S., and was separated by that from Hole 8. The weight of probability seems to be that the first bed in Clark d 8 is the Mandan ophite No. 8.

(138?)

8. Ophite, the Mandan ophite 10 mm. 229

Amygdaloid d 8. 25-30 = 5, at 25-33 0.03 Cu.
Chloritic amygdaloidal trap d 8. 38 = 8
Trap d 8. 38-254 = 216
The amygdaloid is brecciated and prehnitic. The trap markedly mottled.

at 75,	91,	131,	153,	192,	223,	230,	254 feet they are	
5,	7,	9,	10,	10,	8,	4,	0? mm. across	

9. to 11. Cf. Clark d 7. 40-46
Porphyritic melaphyre
Amygdaloid d 8. 254-260 ? = 6
Trap d 8. 260-304 = 44
Poor samples of amygdaloid

The trap shows one small feldspar phenocryst (Cf. d 9. 375-390) and the feldspar ground is rather coarse, while there is no conglomerate at the base there is in No. 7 at a corresponding point (Clark d 7. 40-46), being the first of three such belts which also are represented here.

12. Ophite 5 mm. (97)

(624)

Cupriferous amygdaloid d 8. 304-314
Trap d 8. 314-394

The amygdaloid is red and white with copper and prehnite. The lower amygdaloid trap is faint and occasionally has forms suggesting porphyritic crystals. The trap is fine grained and compact to 327, then at

360,	378,	386 feet shows mottles
5,	3,	2 mm. across.

Cf. Manitou f. 31
Amygdaloid d 8. 394-401 = 7
This is well marked,—probably base of bed above.

13. Amygdaloid conglomerate d 8. 401-438 (37)

(651)

Thick, well-marked, with red sediment and black scoria, and black and white amygdaloid fragments. Cf. Clark d 7. belt at 126 and 46. It belongs evidently to the Houghton conglomerate set.

14. Ophite 2 mm. (55)

(704)

Trap d 8. 438-493 = 55
The mottles are: at 460 and 470 feet.
2 and 1-2 mm. across.

The relations of trap to amygdaloidal conglomerate are as in Nos. 2 and 3 and 8 and 9 of Clark drill hole 1.

At d 8. 483-494 0.03 Cu in the hanging of the porous bed.

23

15. Amygdaloid conglomerate d 8. 493-517, (24)

At 494-503 0.05 Cu; 503-521 0.03 Cu. (728)

Like the Bed 13. Somewhere near the Montreal lode.

16. Trap d 8. 517-522 (733)

17. Melaphyre (33)

Amygdaloid d 8. 522-531 = 9.

Amygdaloidal trap d 8. 531-555 = 24.

At 548-560 trace Cu.

The amygdaloidal part is red and white, the trap is fine grained and all streaked with amygdaloid to the end. The contact at the base is not plain and this is probably a gush of the underlying flow.

18. Ophite 6 mm. (113+17?) (130)

Trap d 8. 555-666+

From d 8. 555-586 it appears fine grained.

At	590,	597,	605,	620,	656,	666 feet the mottles are
	2–3,	3,	4–5,	5–6,	3,	2 mm. across.

At 560-570	.25	copper.
570-580	1.12	"
580-597	.07	"
597-614	.06	"
614-646	tr	"
646-651	.04	"
651-668	.02	"

Correlating	d 7.	40,	120,	165,	180,	268 ft. with
	d 8.	401,	493,	522,	555,	610 ft., the differences
		361,	373,	357,	375,	342,

average 364. The dip will accordingly be 30½°. The general horizon is unquestionably that of the Houghton conglomerate and the Montreal lode. We may also compare d 7. 165-180 with d 8. 401-438.

Below the Allouez conglomerate (896) ft.

" " Houghton " (241)? ft.

Clark drill hole 7. 652 feet south of No. 8, i. e. 4445 north of Breakfast Lake, and 11. 57 feet above it (192.74 above Lake Superior), about 775 paces N. and 500 W. in Section 8, T. 58 N., R. 28 W. The dip of the hole is 65° to the south. Being 33 feet physically lower than No. 8 it should be about 300 feet geologically lower, and should certainly lap it extensively. The correlations above are satisfactory but imply a dip of 30½°. Such a sudden increase suggests a fault. A northwesterly fault throwing the east side down south between 8 and 7 would apparently steepen the dip.

The record is:

Overburden (40)

13. Amygdaloidal conglomerate d 7. 40-46 d 8. 401 (6)

Perhaps the Houghton conglomerate 9 or the crushed top of the ophite below.

14. Ophite 4 mm. (74)

Amygdaloid d 7. 46-49 = 3

Trap d 7. 49-120 = 71 d 8. 438-493

The mottles appear at	57,	66,	86,	91,	107 feet
They are	1,	2,	3–4,	3,	1 mm. across

Cf. Clark d 8. 438-493

15. Amygdaloidal conglomerate d 8. 120-126 d 8. 493 (6)
It is brecciated. Cf. Clark d 8. 401-438. Both are amygdaloidal scoriaceous conglomerate and have a heavier ophite above than below, and an amygdaloid conglomerate 60 feet below.

16 & 17. Cf. also d 11. Ophite 1 mm. (39)

(119)

Cupriferous amygdaloid d 7. 126-133 = 7
Trap d 7. 137-159 = 26 d 8. 522
Amygdaloid d 7. 159-165 = 6

The amygdaloid shows copper and prehnite. The mottles are at 133 and 145 feet, 1 mm. Cf. Clark d 8. 304-401. This cupriferous amygdaloid is not far from the horizon of the Montreal lode and may be it.

17. Amygdaloid conglomerate Clark d 7. 165-180 = 15 d 8. 522 (15)
Cf. the Montreal lode, also Clark d 8 and d 12; possibly a vein breccia. (124)

18. Ophite 5 mm. (119)
Trap d 7. 180-299 Cf. d 8. 555-668: fine grained to 186, at 188 mottled; at.

228,	252,	268,	277,	295,	297	feet the mottles are
3,	5,	5,	3–2,	2,	1	mm. across.

Note the replacement of amygdaloid by amygdaloid conglomerate. This is the only bed at all comparable with that of the base of 8. Cf. Manitou 41. (243)

19. Ophite 3 mm. (60)
Brecciated amygdaloid d 7. 299-326 = 27
At d 7. 299-316 0.01 Cu
At d 7. 316-325 trace
Trap d 7. 326-359 = 33

At 337,	345,	and 350	feet the mottles are
1–2,	2–3,	and 1	mm. across, then finer.

The breadth of this zone of amygdaloid allies it with the amygdaloidal conglomerates. (303)

20. Ophite 3 mm. (41 + 30?) (71)
Brecciated amygdaloid d 7. 359-374 = 15
At d 7. 357-368 0.01 Cu
368-376 0.03 Cu
Trap d 7. 374-400 = 26
The amygdaloid is red. The trap mottling increases to the end;

at 380,	391,	400	it is
1,	2,	3	mm. across

(374)

Clark drill hole 6. 745 feet south of No. 7, that is 3700 feet north of Breakfast Lake and 1.62 feet above it (182.79 above Lake Superior), i. e. about 500 paces N. and 500 W. of S. E. cor. of Section 8, T. 58 N., R. 28 W. The dip of the hole is to the South at an angle of 60°. It is about at right angles to the beds, and should be about 320 feet below No. 7, which is about 10 feet higher. If we correlate the top of this with the top of the other the dip will be about 30°. There is an uncertainty of full 20 feet.

20. Overburden 25 feet (303)
Ophite d 6. 3 mm.
Trap d 6. 25-55? (30+41+?)
Begins coarsest, at 25 and 50 feet the mottling is 3 and 1 mm. across. This might equally well be the base of 18, or in case of faulting, higher beds, but the beds below would not match.
(374)
(10?)

21. Amygdaloid ? d 6. 55-62
At 53-71 0.03 Cu
Trap d 6. 62-65
This is quite likely not independent, only a gush of the overlying. The amygdaloid is brecciated and not well-marked, the trap fine grained.
(384)

22. Amygdaloid conglomerate d 6. 65-84 (19)
At 71-93 0.02 Cu
Cf. at the Mandan d 1. 648-668 268 ft. below the Montreal lode
(403)

23. Ophite 7 mm. (145)
Trap d 6. 84-229
At d 6. 123-153, 177-203, 219-229 a trace Cu.
At 100, 110, 117, 163, 171, 210 feet the mottling appears to be
2, 3–4, 3, 5, 7–8, 3 mm.
This reminds one of the big flow a hundred feet or two above the Calumet conglomerate, T 5f 49, and 1124-1174 below the Allouez at the Mandan.
(548)

24. Ophite (57)
Amygdaloid d 6. 229-232 = 3
At d 6. 229-304 trace Cu
Trap d 6. 232-286 = 54 (605)

25. Cupriferous amygdaloid d 6. 286-292 = 6 (18)
Trap d 6. 292-304 = 12
It may well be that this belongs with the flow below, being separated merely by a brecciated belt.
(623)

26. Feldspathic ophite (74)
Brecciated belt d 6. 304-307 = 3
Trap d 6. 307-378 = 71
At 327 trace Cu., 335-355 0.01 Cu
367 trace Cu.
Trap from d 6. 311-358 rather feldspathic and fairly coarse; at 355 the mottles are 2 mm. across. (697)

27. (67)
Amygdaloid d 6. 378-379 = 1
At 378 0.05 Cu
Trap d 6. 379-444 = 65
At 395 0.01 Cu; at 409-438 0.01 Cu
The trap coarsely amygdaloid, then ophitic to 387
(764)

28. Brecciated amygdaloidal conglomerate d 6. 444-448 (4)
This is, I presume, the Calumet conglomerate.
Cf. Mandan d 1. 901-920
Base below base of Houghton conglomerate. (768)+

The uncertainties of correlation of the different holes at the level of the Mandan ophite and Houghton conglomerates are so great that a hundred feet or two might readily be added to or subtracted from this.

29. (31)
Amygdaloidal trap d 6. 448-468 = 20
At 449 and 467 trace Cu
Coarse amygdaloid at d 6. 468
Trap d 6. 468-479 = 11
from the base of the Houghton conglomerate (799)

30. Ophite 3 to 4 mm. (127)
Amygdaloid d 6. 479-490 = 11
At 479 0.01 Cu
Trap d 6. 490-607 = 117?
At 521 and 573 feet the mottles are
2 and 3-4 mm. across.
At 496-513 0.01 Cu; at 532 0.01 Cu; at 548 and 560 0.03 Cu; at 588 0.02 Cu; at 602 0.03. Cu.
(926)

(31.) Brecciated cupriferous amygdaloid d 6. 607-617

at 607	0.64 Cu.
at 623	0.055
at 633	0.26
at 634	5.46
at 636	1.89

Trap d 6. 617-636
The trap is fine grained and rather brecciated, too. This ophite is thicker than the grain would warrant, one would think, and the brecciation of the amygdaloid below and the amount of copper lead me to suspect a little faulting, a northeast fault throwing the east side down to south, or a northwest fault throwing the east side up to north.

Clark drill hole 5. 931 feet south of No. 5, i. e. 276 feet north of Breakfast Lake and 6.44 feet above it (187.51 above Lake Superior). The dip of the hole is like 3 and 4, 60°, practically at right angles to the beds, and it should be 390 to 460 feet (according as the dip is 25° or 30°) lower than drill hole 6.

Overburden, sand, gravel and broken ledge 55 feet

(30) Ophite (80 +) (92 +)
Trap d 5. 55-133
Looks fine grained and reddish, weathered at 58, then coarser
At 88 and 123 feet the mottling is
3 and 1-2 mm. (926)

31. Ophite 5 mm. (126)
Amygdaloid d 5. 133-169 ? = 33
Poor, with intercalated streaks of trap to 169 where is a heavy fissure of laumontite.
Trap d 5. 169?-251
At 200-246 0.02 Cu

At 176,	186,	195,	205,	226,	236,	246 ft. the mottles are	
2-3,	3-4,	4,	8 faint	2-3,	1-2,	1 mm.	

Below the Calumet conglomerate, (284)
Below the Houghton (1052)
Below the Allouez (1203)

32. Ophite 6 mm. (121)
    Amygdaloid d 5. 251-271 Calumet amygdaloid?
    At 246-266 0.03 Cu
    At 266-284 0.065 Cu
    Near horizon of Calumet and Osceola lode, but an abnormally heavy foot trap.
    Trap d 5. 271-372
    At 284-310 0.01 Cu, at 310-350 0.02
    The ophitic texture is unusually well-marked down to pinhead size.

At 278-289,	295,	300,	305,	315,	316,	350,	360,	364 ft
1,	2,	2,	3,	7x2 and 4,	6,	1-2,	1,	0.5 mm.

33. Amygdaloid d 5. 372-373
    Trap d 5. 373-379
    At 356-379 0.01 Cu
    Perhaps part of the next flow
34. Feldspathic ophite 4 mm. (91)
    Amygdaloid d 5. 379-381 = 2 (1264)
    At 379-386 0.00 Cu
    Brecciated, red and white
    Trap d 5. to 388 7
    Amygdaloid d 5 388-391 = 3
    Trap d 5. 391-470 = 79
    At 386-430 trace Cu
    430-450 .01
    450-460 00
    460-474 trace
    Coarser feldspathic ophite. Coarsest at about 423 to 435 when the augite prisms attain 7 x 2 mm., then finer.

(35.) Amygdaloid d 5. 470-473
    Well-marked amygdaloid with calcite and copper.
    Note that this does not show much in the sludge which is influenced mainly by trap above.

Clark drill hole A. 544 feet south of No. 5. 2225 feet north of Breakfast Lake, and 31.64 feet above Breakfast Lake. 212.81 A. L. S. Dip of the hole 51° to the north.

Overburden about 20 feet

31. Ophite
    Trap d A. to 190
32. Ophite
    Amygdaloid d A. 190 (Calumet amygdaloid?)
    At 190-206 0.04 Cu; at 225 0.03; at 236 0.03; at 239 0.06.
    Trap d A. to 239

Clark drill hole 4. 773 feet south of No. 5, i. e. 1996 feet north of Breakfast Lake and 9.14 feet above it (190.30 above Lake Superior). The dip of the hole is, like 3 and 5, 60°.

Overburden about 18 feet

33. Ophite
 Trap d 4. 18-43(?)
 At 18-28 0.02 Cu
 Begins broken up for two feet and at 30 feet a 2 mm. ophite?
 Ophite (97)

34. Amygdaloid 43-50 (?)
 At 28-64 trace Cu
 Trap d 4. 50-140
 At 64-67 0.02 Cu
 121-146 trace (1264)

35. Doleritic ophite 12 mm. (247)
 Amygdaloid d 4. 140?-160
 At 121-146 trace Cu
 Trap d 4. -367
 At 171-198, 227-260, 328-351, 357-370 traces Cu

At	253,	299,	317,	346,	363 ft.
	10,	10,	12,	5,	1–2 mm.

Doleritic streaks occur at 253 and 256-260 which may represent the welding together of two flows.

It is coarsest at about 317,—and there are chlorite seams.

The grain is irregular. Cf. Empire b 35 (d 2. 199-360), also Manitou 3, Belts 51 to 54, just above the Kearsarge conglomerate.

Below supposed Osceola (369) ft.

Below Houghton conglomerate (1511)

36. Kearsarge amygdaloid?
 Amygdaloid d 4. 367-375
 Fine grained, with porphyritic crystals and copper in large amygdules.
 Trap d 4. 375-386

37. Wolverine sandstone d 4. 386-397 (10)
 At 385-400 0.06 Cu

Red sandstone and shale at first at 84° 20′ to core, passing at 391′ into fine grained conglomerate, and at base there is a much disturbed transition to trap. At first this was taken to be the Kearsarge conglomerate and certainly the overlying ophites and distances to Calumet conglomerate, Osceola amygdaloid conglomerate, etc., agree, but the Kearsarge group seems largely cut out of the section. Presumably the faulting displacements grow greater to the south as we approach the area of disturbed felsite intrusions described by Hubbard. The grain of the doleritic ophite above 12 mm. at apparently only 50 feet from the margin is altogether too coarse, and is, to my mind, decided indication of a fault. 35 may be over the Kearsarge or it *may* be Manitou 3, flow 66 in part. Such a fault (if a nearly vertical fissure) would, however, imply a horizontal displacement or throw by which the lower part of the section was moved north 1400 feet or a strike fault with a dip steeper than 30° and a very considerable uplift of the lower part and drop of the upper.

Of so large a cross-throw there should be more evidence in the topography

than there is. The Montreal River valley may well mark the course of some such strike faults.

38. Feldspathic ophite (1542)

Trap d 4. 397-450+

At 400-416 trace Cu

416-450 0.01 Cu

At d 4. 397-398 much disturbed, specked and decomposed to 406.

Much seamed in various directions; parallel to the core, at 40° to the core and at 60° nearly at right angles to the other, and also parallel to the dip?

Clark drill hole 3. 754 feet south of No. 4, i. e. 1242 feet north of Breakfast Lake, at 15.77 feet above it (196.94 feet above Lake Superior). The dip of the hole is steeper than in No. 2 (60°). As it is 2458 feet south of No. 6 and 14 feet higher, it should be from 1100 to 1270 feet lower (according to the dip assumed) or 592 to 800 feet below the bottom of it and 573 below the Houghton. The feldspathic glomeroporphyritic character of the top at d 3. 130-140 reminds one, however, of beds below the Kearsarge, those exposed in Manitou 7 d 6 S., Nos. 89-91. In that case the heavy bed above, No. 35, might also be compared with Manitou 7 b. 80 or 82.

Overburden, sand and gravel 22 (1543)?

(38) Feldspathic ophite or melaphyre (112+?)

Trap d 3. 22-140

At 22-37 trace Cu

The trap gets finer from 112 on and from 130-140 is markedly glomeroporphyritic. Cf. Manitou d 7. b 59 (1655)

39. Feldspathic ophite 141

Brecciated veined (amygdaloid ?) d 3. 140-143

Amygdaloid trap d 3. -156

The trap is a chloritic feldspathic ophite, coarsely amygdaloidal

Trap d 3. -281

At 185-213 0.02 Cu

213-230 trace

230-324 0.02

40. "Amygdaloid" d 3. 281-287 (1796)

"Trap" d 3. 282-294 (13)

1. Amygdaloid conglomerate 9

"Amygdaloid and sandstone" d 3. 294-303 (1818)

"Trap" d 3. 303-306 3

(42.) Feldspathic ophite (1821)

Amygdaloid d 3. 306-310

Trap d 3. 310-467

At 407-433 trace Cu

433-453 0.02 Cu

453-467 trace

Equivalent to d 2. 13-248 presumably

If No. 37 were the Kearsarge conglomerate, Manitou 3 b 5 6, this would be Manitou 3 b 6 6.

Clark drill hole 2. 500 feet north of the Breakfast Lake datum and 27.02 feet above it and 208.19 feet above Lake Superior. Its dip is 52°.

A correlation of Hole 1.199-206-218 with 2.467-487 seems close, also

1.152	2.421
1.110	2.378
1.84	2.353

No. 2 at 32 feet would be on a level with the beginning of No. 1 and 466 feet from it.

The dip to be inferred would be 30°½ (302?)

42. Doleritic ophite 7 mm.

Trap d 2. 13-248;

At 108-143 and 240-256 trace Cu

The hole begins at 13 in a coarse mottled (6-5) ophite and at d 2.20 is dolerite which, we assumed, corresponds to d 3.380. This would make the top of this flow about correspond to d 3.281-306, thus making d 3.306-467 and d 2. 13-248 one thick flow.

At 13,	32,	35,	50,	233 feet the mottling is
4–5,	5,	7,	7,	2–3 mm. respectively

But the augitic mottling is scanty; the doleritic streaks frequent and coarser toward the center. Doleritic seams occur at 20, 22, (with 2-3 mm. feldspar) 31, (3 mm. feldspar) 38, 48, 50-53, 117-118 feet. It is heavily seamed with laumontite at 62-67; at 38 is a minute speck of copper.

43. Feldspathic amygdaloidal melaphyre 52

Amygdaloid d 2. 248-257 = 9

At 240-292 trace Cu

292-311 0.02 Cu

Amygdaloidal trap d 2. 257-300 = 43

Beginning in a red, fine grained, chloritic amygdaloid, then at 256 veined, brecciated, siliceous, then (from 257 on) coarse feldspathic with grey and white amygdules at first, then coarsely feldspathic, with green amygdules and a doleritic appearance,—coarsest at 272, then growing finer.

44. Feldspathic melaphyre (glomeroporphyritic ?) (53)

Amygdaloid d 2. 300-302

At 292-329 0.02 Cu

Markedly fine grained, then coarser calcitic.

Trap d 2. 302-353; cf. Hole 1-78.

At d 2. 308 seamed and possibly with porphyritic crystals (10 mm. or so). Beside that 1 to 2 mm. feldspar on red ground.

At 325½ greenish, chloritic, altered.

At 328 a prehnite copper seam.

At 339 prehnite seams and the rock is specked to 356.

To 351 reddish feldspathic.

Cf. Manitou 7. b. 90

(45) Feldspathic melaphyre (25)

Amygdaloid d 2. 353-370 with white, then green, irregular amygdules like d 2. 300.

Amygdaloidal trap d 2. 370-378 (cf. 1 to 104).

Feldspathic with chlorite amygdules, inclining to doleritic type.

(46) Amygdaloid d 2. 378-388; d 1. 104-112 (43)

Well-marked to 382; with maroon base and small white amygdules changing to coarse feldspathic with chlorite amygdules.

Trap d 2. 388-421; d 1. 112-152

Coarse feldspathic

(47) Amygdaloid d 2. 421-425; d 1. 152-166 (46)
and
(48) Red and white, with seamed laumontite contact becoming chloritic and coarser at base.

Trap d 2. 425-467; d 1. 166-199

49. Sandstone and amygdaloid conglomerate d 2. 467-487; d 1. 129-218 (20);
All along from d 2. 453-496 a trace of copper, and at d 1. 216 trace
Dark brown to red with fragments of black and white amygdaloid at first not very abundant. The bedding is practically perpendicular to the hole. There are also seams at 23° to core perhaps about vertical that fault the sandstone bands a few millimeters. There is more and more enclosed amygdaloid toward base.

(50) Amygdaloidal ophite (80)
Amygdaloid d 2. 487-490 = d 1. 218
Of same type as the pebbles in the bed above.
At d 2. 482-496 trace Cu
Trap d 2. 490-493
Amygdaloid d 2. 492-511
At d 2. 482-521 trace Cu
Trap ? d 2. 511-514.
Amygdaloid d 2. 514-540.
Trap d 2. 540-567
At d 2. 538-560 trace Cu.
The amygdaloid is of the same type as the pebbles in the conglomerate above. The bottom trap is a fine grained ophite, with mottles at 554 feet ½ to 1 mm. across.
Beds 51, 52, and 53 are found only in drill hole 1

(54?) Ophite ½ mm ? (31?)
Amygdaloid d 2. 567-573 = 6
Trap d 2. 573-598 = 25
The amygdaloid is well-marked but many of the amygdules are empty; at 573-598 is ½ mm. mottling.
Amygdaloid d 2. 598-600.

Clark drill hole 1. 15 feet north of Breakfast Lake and 31 feet above it, i. e. 184.27 A. L. S. Dip of hole 52° to S.

(44) Feldspathic ophite (10 +)
Trap d 1. 68-78 = d 2. to 353
Begins coarse with 1-2 mm. feldspars
At 74 feet is a seam.
Toward the base it grows fine grained and in a way glomeroporphyritic.

45. Glomeroporphyrite 26
Amygdaloid d 1. 178-94; d 2. 353-370
Poor, red, with small porphyritic crystals
Trap d 1. 94-104; d 2. 370-378
Feldspar and chlorite conspicuous

46. Feldspathic ophite (48)
Amygdaloid d 1. 104-112; d 2. 378-388
Grey, markedly brecciated (108-110), coarse with porphyritic crystals of feldspar
At 113-128 0.03 Cu
128-148 0.02 Cu

Trap d 1. 112-152
in No. 2 hole none
Chloritic, angular, doleritic; toward 134-144 coarsest, feldspathic slightly ophitic.

47. Porphyritic melaphyre?
Amygdaloid d 1. 152-166 = 14
Fine grained, with small, white amygdules on red ground, and also what appear to be pseudomorphs of altered feldspar.
Trap d 1. 166-189
Cf. Beds 116 to 123 of the Manitou section.

48. Amygdaloid d 1. 189-196
Well-marked, and at 193½ almost conglomerate, with small amygdules, chlorite and laumontite and calcite.
Trap d 1. 196-199 = 3
Fine grained black
Quite probably not a separate flow.

49. Sandstone d 1. 199-206 = 2. 467-487
Amygdaloid and amygdaloid conglomerate d 1. 206-218 brown, then red, with amygdaloid 204-6 and at base a conglomerate of chloritic grains; angle with hole 11⅓°, probably indicating a dip near 26° rather than one of 48°. In many respects d 1. 152-206 resembles d 4. 367-397.
Amygdaloid or amygdaloid conglomerate from d 1. 206-218 evidently corresponds to the lower part of d 2. 467 to 487.

50. Amygdaloidal melaphyre. (59)
d 1. 206-218 may be amygdaloidal top of 50 or bottom of 49
At 199-216 trace Cu.
Trap d 1. 218-227 trap, fine grained prehnite amygdules, porphyritic.
Amygdaloid d 1. 227-228, marked, but with small amygdules.
Amygdaloid and trap d 1. 228-236
Amygdaloid d 1. 236-241
Trap d 1. 241-243
Amygdaloid d 1. 243-245
Amygdaloid d 1. 245-259
Trap d 1. 259-265

51. Amygdaloid conglomerate d 1. 265-275 (10)
Red matrix and dark amygdaloid pebbles.
In No. 1 this was not noticed and the question whether it is a fault breccia might be raised.

52. Trap d 1. 275-282.

53. Amygdaloid d 1. 282-289.
Strong with small white (calcite) or pink laumontite amygdules.
Amygdaloidal melaphyre d 1. 289-295.

54. Ophite, faulted, 3 mm.
Amygdaloid d 1. 295-301.
Like d 1. 282-289
Clasolitic amygdaloid d 1. 301-304
Amygdaloid d 1. 204-325
Trap d 1. 325-437.
At d 1. 364-376 and at 399-410 0.03 Cu, evidently connected with the chlorite seams.
At d 1. 346 the mottles are white and red.

At 337, 341, 346, 351, 358, 364 feet the mottles are:
1, 1 to 2, 1 to 3, 2, 3, 1 to 2 mm., then from 367-398 heavily seamed with chlorite, and mottled about the same, 2 mm.
At 412 and 420 feet the mottles are:
2 to 3, and 3 mm. and at 430 an interesting piece of core shows a seam with 2 mm. mottles on one side, ½ mm. on the other.
Cf. d 2. 573-598. Then it is fine to end.
At d 1. 410 to 425 trace Cu.

55. Amygdaloid d 1. 437-440.
At 425-444 0.03 Cu.
Hard, very minute amygdules, light red.
Amygdaloid trap d 1. 440-457.
Compact, with minute amygdules.

56. Amygdaloid d 1. 457-459.
Trap d 1. 459-468.
Same type as at d 1. 437, peculiar, epidotic and siliceous, passing into a regular porphyrite, with small 2-3 mm. green altered feldspar laths on a red ground, like the Ashbed type.
Cf. Manitou b 90-91 and 116-117 and Central mine belts 97-115 which are 1577 to 2975 feet below the Wolverine sandstone
2773

4350 5748 ft. below the Houghton conglomerate.

57. Amygdaloid d 1. 468-470.
Trap d 1. 470-490.

58. Feldspathic ophite 5 mm. (133)
Amygdaloid d 1. 490-499.
At first brecciated and clasolitic (like amygdaloid conglomerate) then chloritic.
Trap d 1. 499-622.
Feldspathic, growing coarser.
At 520, 540, 560, 619 feet the mottles are
2, 4, 5, 2? mm.
At d 1. 590-609 0.02 Cu.

59. Feldspathic ophite. (37)
Amygdaloid d 1. 628-630.
Coarse, poor, calcitic.
Trap d 1. 630-660.
Reddish, with laumontite seams.

60. Feldspathic melaphyre. (72)
Amygdaloid d 1. 660-669.
Trap d 1. 669-732.
Feldspathic, with chloritic seams and a bomb.

61. Melaphyre. (15)
Amygdaloid d 1. 732-738.
Trap d 1. 738-747.
Dark green. Is this a sign it is near a fissure?
Note the Cu; at 720-765 0.02 Cu.

62. Ophite 5 mm. (111)
Amygdaloid d 1. 747-750.
Trap d 1. 750-858.
At 794-807 0.03 Cu.

807-813 trace Cu.
At 770, 787, 790, 811, 830–838, 847 feet the mottles are
2–3 mm, 5-7, 5, 5, 3, 2 mm.

63. Sediment shading into red amygdaloid conglomerate d 1. 858-860.
At 842-858 0.02 Cu, though none was reported from 858-936.

64. Feldspathic ophite 3 mm. (78)
Amygdaloid d 1. 860-863.
Trap d 1. 863-938.
Seamed d 1. 863-866. At d 1. 876, 2-5 mm. mottles; at 897-900 probably an altered seam, but like those puzzling amygdaloids above, looks felsitic, red and white speckled.

65. Sandstone d 1. 938-943
An amygdaloid conglomerate or clasolite.
All sandstone d 1. 938-940.
At 939-961 trace Cu.
With amygdaloid d 1. 940-943.

66. Trap d 1. 943-947.

67. Epidotic seam and fine grained, doubtfully a new belt d 1. 947-950
Mottled trap d 1. 950-960.

68. Scoriaceous top d 1. 960-961. 32
At 961-972 0.02 Cu.
Amygdaloid d 1. 961-965.
Trap d 1. -992. (15)

69. Amygdaloid d 1. 992-996.
At 972-984 trace Cu.
Trap d 1. 990-1007.

70. Scoriaceous amygdaloid or amygdaloid conglomerate d 1. 1007-1012
At 1001-1011 0.02 Cu.
On the whole Manitou 7-5 and 6-5 correspond to Clark 3 and 4, and Manitou 7-8 and 9 S, with feldspathic smaller beds to Clark Hole No. 1.
Seamed d 1. 863-866. At 876 2-5 mm. mottles.

The lowest beds of this Clark-Montreal section should outcrop about 1,600 feet south of Breakfast Lake. It is just about a mile from Hole 1 to the Bohemia conglomerate at the center of Section 22, T. 58 N., R. 28 W., from which point Hubbard had studied the cross-section pretty carefully. Assuming the dip to be 30°, this would give 2,640 feet, of which Hole 1 covers 1,012, leaving unexplored thereby 1,628 feet and probably more, as according to Hubbard, the Bohemia conglomerate dips nearer 54°. In this interval should be the horizon of the Arcadian-Isle Royale lodes. The beds of Hole 1, feldspathic ophites, are, in fact, not unlike the belts of the Arcadian section, Holes 4 and 22, belts 76-83, just above the Isle Royale. In the interval are some outcrops but no continuous section has been made. No conglomerates or sandstones are known. The lower 200 paces contain traps and conglomerates and we then have, using Hubbard's letters and Plate III of Vol. VI, Part II:

O. Felsitic conglomerate	20 paces	37 ft.	
N. Melaphyre one or more thin beds	50 paces	93	130.
M. Felsitic conglomerate	240 paces & less	84	214
L. Felsite, spherulitic Sp. 17037 Mt. Houghton felsite.	330 paces	615	829
K. Conglomerate	20 paces	37	866
(K, M and O merge and make up the Bohemian conglomerate, loc. cit. p. 28) No. 8			
J. Felsite Sp. 17036 A, amygdaloid	50 paces	93	959
H. Conglomerate and breccia of felsite at top, and basic or amygdaloid conglomerate at base, No. 7?	25 paces	46	1004
G. Felsite porphyrite Sp. 17039, amygdaloid	40 paces	74	1078
F. Conglomerate, amygdaloidal. See Plate III b.	10 paces	18	
E. Porphyrite, Sp. 17033, amygdaloid, andesitic, microlitic	60 paces		112
D to B. 9 melaphyres with amygdaloid or amygdaloid conglomerate tops. These amygdaloid conglomerate tops under Conglomerate 6 are marked also around Portage Lake. It will be noted that they grow more massive. They are respectively about	20 paces	37	1115
	15 paces	28	1143
	15 paces	28	1171
	40 paces	74	1245
	15 paces	28	1273
	20 paces	37	1310
	30 paces	56	1366
	70 paces	130	1496
	60 paces	112	1608
A. Heavy ophite: continues through to Mt. Bohemia. Cf. the Mendota section, and the Mabb ophite.		100+	
Total?			

§ 3. EMPIRE. (See Fig. 24 in envelope.)

The next section in order is that of the Empire, about $3\frac{1}{4}$ miles west. The beds above the base of the Greenstone are probably about as before. The Greenstone and Allouez conglomerate were just missed in the drilling, but are placed in Figure 24 from my field notes and observations on the grain of the Greenstone at its nearest exposure in the bluff north of the section.

The section is not far from the Old Iron City vein of Whitney, Hill and Stevens. There was a "Manitou" on Section 8 and a "Cape" on the west part of Section 7, working cross-veins just below the Greenstone.

Abstract of Empire Section.

Missed Allouez conglomerate.

1.		
2.	1. 28-37	
3.	105-175 Felds. Oph. Faulted (8 mm.)	
4.		
6.	1. 295-365 " " " (7 mm.)	
7.	77 " " " (5 mm.)	
8.	1. 451-462	410
9.	1. 462-548 78 Oph. " (7 mm.)	
10.		
11.		
12.	Houghton 1. 629-643	585
13.	Oph. (1-2 mm.)	
14.	Acg.	
15.	Oph. (2-3)	
16.	Acg.	
17.	?	
18.	Acg.	
19.	Oph.	
21.	Montreal 193	
20.	Acg. & O. (6 mm.) (140)	
21.	Oph. (68)	
22.	Oph. (85)	
23.	Acg? (43)	
24.	Oph. (7 mm.) (130)	
25.	(63)	
26.	Calumet conglomerate 4. 600-606 M. f. 44	
28.	710	
30.	Feldsp. Oph. (7 mm.) (140) 320	
	Gap in section. M. f. 49 300 feet? Including perhaps Osceola Am.	
31.	Osceola?	
32.		
33.		
35.	Dol. Oph. (7-10) (141)	
38.	Kearsarge conglomerate	424′

39.				744
41.	Sediment			
42.	Dol. ophite		(162)	
43.	Epidotic sandstone			
45.				
47.				
48.				
50.	Ophite 2.1091		(160+)	455
	Gap in section in which is Wolverine and Kearsarge Amygdl.			
51.			(400+)	
52.	Congl. 5.	715-720		1020
53.				

The Empire section of Keweenaw Copper Co. is on the north and south line in the old "Empire" and Wyoming mining properties 1500 paces west in Section 14, T. 58 N., R. 28. W.; The 0 of the section is on the Greenstone Range at an elevation of 572 A. T. From notes furnished by the engineer, A. H. Sawyer, examination of the cores and trip of Aug. 1907., by A. C. Lane, Contractors Longyear and Hodge.

Empire drill hole 1 is on a flat 450′ above Lake Superior and is 700′ south of the N. line of 14, 2000′ N. of Montreal River. No. 1 seems just to have missed the base of the Allouez conglomerate, which is thus 600 or 700 feet farther south than indicated on Plate IV of Volume VI, Part II.

It is 700 ft. south of the section 0, while at about 3+98′3 of the section the mottling is 10 mm., rapidly increasing as we go up a 26° slope, to say 35 mm., at 176 to 200′ N. of the road which is 154′ N. of the hole, i. e. 350′ south of 0 of the section. On the other hand the grain shows that the hole could have but barely missed the conglomerate. The dip of the correlation of the Houghton conglomerate is 25°, which agrees well with 26° found N. of Breakfast lake. The reduction factor from depth to thickness is .906

1. Melaphyre (16)
   Trap d 1. 9-28 = 18
2. Ophite (70)
   Amygdaloid d 1. 28-37 = 9
   The amygdaloid is coarser from 29-33, and brecciated perhaps at 31
   Trap d 1. 37-105 = 68
   The trap shows 3-4 mm. mottles at 99
3. Ophite (shattered) (64)
   Amygdaloid d 1. 105-107 = 2
   Trap d 1. 107-175 = 68
   This shows at 128 a 5 mm. mottling, at 160 8 mm. (?), and remains a coarse feldspathic ophite to 167, when it passes a fault, and is suddenly finer.
4. (25)
   Amygdaloid d 1. 177-185 = 8
   Trap d 1. 185-204 = 19
5. Ophite (36)
   Amygdaloid d 1. 204-209 = 5
   Trap d 1. 209-244 = 35
   At 230 has 3 mm. mottles?, at base brecciated.

5. (46)
Amygdaloid d 1. 244-250 = 6
Trap d 1. 250-295 = 45
The hole crossed at 280 a vein at an angle of 30°

6. Ophite, feldspathic (64)
Amygdaloid d 1. 295-312 = 17
Trap d 1. 312-365?=53
The trap has 7 mm. mottles at 335, 4 to 5 at 355, while at 357 there are signs of a slide and finer grain.

7. Feldspathic ophite (77)
Amygdaloidal trap passing into feldspathic ophite d 1. 365-409 = 44
This may be part of the bed above, disturbed by faults
At 404 is a prehnite seam.
Chloritic amygdaloid d 1. 409-415 = 6
At d 1. 423 is a marked seam with a slip at 45°
Trap d 1. 415-451 = 36 410
Mottles up to 5 mm.

8. (10)
Amygdaloid d 1. 451-456 = 5
Trap d 1. 456-452 = 6

9. Ophite (78)
Amygdaloid (poor) d 1. 462-476 = 14
Trap d 1. 476-548 = 72
Seams at 45° to core; at 491 7 mm. mottles, at 520 5 mm.
Apparently partly cut out.

10. Amygdaloid d 1. 548-554 = 6 (32)
Amygdaloid trap d 1. 554-576 = 22
Fine trap d 1. 576-583 = 7
The whole group of beds above or at least 8-10 seem to represent the Mandan ophite disturbed by faults with a steeper dip than the beds, i. e. about 45°.

11. Ophite (42)
Amygdaloid d 1. 583-584 = 1
Trap d 1. 584-629 = 45
Brecciated, 1-2 mm. mottles. Cf. Clark 8. (see p. 176) 254-304, No. 12.

12. Houghton conglomerate. (13)
(585)

Amygdaloidal conglomerate d 1. 629-643 = 3. 60 to 73. The dip according to this correlation is 24.5°. Dark red, brecciated. Cf. 750 feet at the Delaware, 576 at the Mandan & Medora d 12. 540, 689 feet at the Central.

13. Ophite (37)
Trap d 1. 643-683 = 40 and d 3. 73-108 = 35
Mottles 1 to 2 mm.

14. Amygdaloid conglomerate? First below Houghton. See brecciated (0 to 16), amygdaloid below.

15. Ophite (62)
Amygdaloid, brecciated d 1. 683-686 = 3
Trap d 1. 686-751 = 65
Cf. d 3. 108-183 (14 and 15) = 75
The mottles are 3 mm. at d 1. 722 feet, and 2-3 mm. at d 3. 152 feet.

16 to 18. Amygdaloid conglomerate. Second below Houghton (41)
Brecciated d 1. 751 to 796 = 45
There is a speck of copper at 793. This heavy bed corresponds to 16, 17 and 18 in No. 3. Is this the Montreal lode or the one above?
19 Ophite (55)
Trap d 1. 796-855
Coarsest at 833. Total below the Houghton conglomerate. 212 (193)
20. Ophite, the Montreal and foot.
Brecciated amygdaloid d 1. 855-860
Trap d 1. 860-907
All ophite up to 5 mm. across.

Empire drill hole 3. 303 above Lake Superior on flat at foot of well-marked terrace front. 1625 feet S. of beginning, i. e. 925 feet S of Hole 1. Dip 90°. Dip of beds about 25° as before, though he correlation with the Houghton conglomerate in No. 4 would give nearer 30°. Reduction factor about 0.82 to 0.88.

(9 or 11) Ophite
Trap d 3. 22-60 = 38
Getting finer from 5 mm.
12. Houghton conglomerate 60-73, greenish massive at top, then dark red and black amygdaloid conglomerate.
13. Ophite (32)
Trap d 3. 73-108 = 35
Specked, decomposed, original weathering? to 78′, mottles at 83 and 100 feet are 1 mm. across.
14. Amygdaloid conglomerate. First below Houghton. (16)
Brecciated d 3. 108-126 = 18 (48)
15. Ophite (52)
Amygdaloid trap d 3. 126-133 = 7 (101)
Trap d 3. 133-183 = 50
Mottles are 2, 3-2, and 2 mm. at 144, 152 and 170 ft. respectively.
16. Amygdaloid conglomerate? Second below Houghton.
17. Ophite (33)
Brecciated amygdaloid d 3. 183-193 = 10 (134)
Amygdaloid trap d 3. 193-200 = 7
Trap d 3. 200-219 = 19
Mottles at 207 1 mm.
18. Amygdaloid conglomerate? Third below Houghton.
19. Ophite (62)
Very brecciated amygdaloid d 3. 219-226 = 7
Skeined amygdaloid trap d 3. 226-231 = 5
Trap d 3. 231-287 = 56
At 265 is a seam dipping 25°-26°, then it is finer with mottles 2-3, 2, and 1 mm. at 261, 271 and 280 feet respectively.
Total below Houghton conglomerate 214= (195) ft.
20. Montreal lode ophite. Fourth below Houghton
Brecciated amygdaloid d 3. 287-311 = d 1. 855-860 = d 4. 12-47?
Ophite d 3. 320+ = d 1. 860-907+40+ = d 4. 47-168
This is a marked ophite. Cf. Clark d. 6. 84 to 229? In the Manitou 3 section it is (224) feet from the base of the Houghton conglomerate to the Montreal lode and it is the third below the Houghton. On Manitou

7 it is supposed to be only (150) from the top of the Houghton, with a heavy ophite beneath. At the Medora d 12. 743, d 2. 277, d 1. 350, d 9. 365, d 3. 339 are the depths to the top of a fairly persistent amygdaloid with a good-sized ophite beneath,—something like 200 below the Houghton.

As d 3. 73 = d 1. 643 and d 3. 287 = d 1. 855, the almost identical length of the holes of the same thickness of the beds would indicate almost the same dip. (335)

Empire drill hole 4 is at 2067 of the section 542′ S. of 3. Its elevation is 282′ above Lake Superior. Dip 90°. The dip of the bed is probably 25° to 30° and a reduction factor of .88 may be nearly right. The Montreal lode correlation implies a dip of 28.5° and that with No. 2 Hole 29°.

Surface 12

(20) Montreal lode ophite d 4. 12-168 = 3. 287+ (137)

The well-defined mottling is respectively

1, 1½, 2, 2–3, 3, 8x3&4, 4, 5, 6 mm.
at 50, 55, 58, 70, 82, 87, 90, 99, 107,
5, 4–5, 5–6, 4–5, 2, 1, ½, mm. at
111, 120, 141, 136, 147, 158, 164 feet, indicating a rate of increase of something like 1 mm. in 10 (9) feet, or 1 : 2,750 = .00036. From 12-47 it is fine grained specked with a little copper at 19 feet, amygdaloidal and ophitic, evidently the eroded top of a flow.

21. Ophite (66)

Amygdaloid d 4. 168-171 = 3 (398)

Poor, brecciated red and white.

Trap d 4. 171-243 = 72

The trap is fine grained brecciated to 180 where the mottling begins to be noticeable. It increases to 218, then becomes finer and is beautifully developed.

22. Ophite (84)

Poor amygdaloid d 4. 243-256 = 13 (482)

Trap d 4. 256-338 = 82

Coarsest about d 4. 301-313

23. Amygdaloid conglomerate? (43)

Brecciated belt d 4. 338-386 = 48

This is a broad brecciated and amygdaloid belt. It is not distinctly conglomeritic, but too thick for a normal amygdaloid. This with the heavy ophite below represents a persistent coarse ophite. Medora d 1. 648-835 (7 mm.); d 3. 653 to 812, M. d 3. 620-749 (7 mm.) Clark flow 23.

24. Ophite (126) (524)

Trap d 4. 386-530 = 144 ?+

Irregularities in grain seem to indicate disturbance. It is coarse close under the brecciated belt. The mottles are respectively

7, 4 to 8, 3 to 4, mm. across at
447, 449–492, 490

It is finer about 530-537 but there is no well-marked amygdaloid, but fine trap. (650)

25. Ophite (63)

Trap d 4. 530-537

d 4. 537-600

Coarsest at 569 feet, with 4-5 mm. mottles. The top is a fine grained veined ophite.

A bed about 60 feet thick over the Calumet occurs in the Medora and Delaware sections, and in the Central Mine, where it is also No. 25; at the Clark Montreal it is No. 27. (705)

26. Calumet conglomerate (6)

Conglomerate d 4. 600-606

At d 4. 601 felsitic. There is copper in the conglomerate and in the hanging (710)[1]

At the Central the distance base of Houghton to base of Calumet is 815
At the Delaware (Manitou) " " " " " " Calumet is 745
At the Medora " " " " " " Calumet is 710
At the Clark Montreal " " " " " " Calumet is 728

27. Foot of Calumet conglomerate. Ophite (69)

Brecciated d 4. 606-620 = 14
Trap d 4. 620-682 = 62

Cf. M. 2. S. 88-172, at Calumet 109 ft. thick, Medora d 10. 194-245?, Clark 6. 448-479.

28. Feldspathic melaphyre (111)

29? Poor amygdaloid d 4. 682-688 = 6 (180)

Trap d 4. 655-805 = 117

The trap is generally fine grained, from 722 seamed and at 733-742 brecciated, only faint ophitic. There may be a contact at 733; cf. M. d 3. 2. S. 244-250, Clark d 6. 479-607. At Calumet, too, the next 160 feet are sometimes, not always, counted together.

30. Feldspathic ophite. "Calumet amygdaloid" and foot? (140)

(320)

Amygdaloid d 4. 805-813 = 8
813-948 = 135

From 817 on some ways many laumontite seams. The mottles are respectively

3, 7, and 1 to 2 mm. at
845, 880, and 940

below which it is fine grained and specked. Cf. M. d 3. 2. S. 334-459, Clark d 6. 607+. At Calumet it is 130 feet thick.

31. "Osceola" and foot ophite, or more probably Calumet.

Amygdaloid d 4. 948-970

Brecciated, poor, chloritic.

Is this the Osceola or Calumet amygdaloid? The hanging of the "Osceola" lode at the Manitou in d 7. 1. S. is also about 320 feet below the Calumet conglomerate. Cf. Clark d 5. 251-271. A correlation with the first belt of Empire hole 2 would imply a dip of 29°, but a steeper dip is probable, in which case one stout bed of ophite may be omitted.

[1] Plus 50 feet faulted out?

Empire drill hole 2 is at 3700 feet on the section, 950 ft. S. of the Montreal River, and 262 above Lake Superior,—30 feet above the bottom of Montreal River. Dip 90.° Dip of beds 29°?+ To reduce the depth to thickness multiply by .88. But there are some reasons for believing that the dips are considerably steeper at the bottom of the hole. So that below the Kearsarge conglomerate we assume a dip of 38.5° and multiply by .78 (320)

Surface 27 feet.

31. Osceola amygdaloid and ophite foot (54)

Brecciated amygdaloid d 2. 27-32 (374)
With prehnite, calcite, copper.
Trap d 2. 32-88
A feldspathic ophite coarsest (3-5 mm.) about 51
Cf. Clark d 5. 271-372.

32. Melaphyre (20) (394)

Amygdaloid d 2. 88-93
Trap? brecciated d 2. 93-111

33. Feldspathic ophite (64)

Amygdaloid? (458)
Minute green chloritic amygdules, a red amygdaloid with glomeroporphyritic feldspar.
Cf. Medora d 1. 567
Trap d 2. 111-184
Chloritic, feldspathic, when coarse faintly mottled.
Seams perhaps parallel to the bedding.[2] Dip 35° to 45°
Cf. 32 and 33 with Clark 33 d 5. 372 to 470. Both have alternations of amygdaloid at the top, and a coarse feldspathic ophite beneath. (458)

34. Melaphyre (13)

Amygdaloid d 2. 184-194 = 10 (471)
Trap d 2. 194-199 = 5
Very probably only a gush of the underlying.

35. Doleritic ophite (141)

Amygdaloid d 2. 199-210 (612)
With seams of calcite and copper. Cf. the lode at the Clark 4. 35.
Amygdaloidal trap d 2. 210-216
Trap d 2. 216-360
At 244 are big seams and the trap is doleritic, coarse but only faintly ophitic. At 254 the mottles appear to be 6-8 mm., and at 320 7-10 mm. across, then finer. There are laumontitic seams at 320. Cf. Mandan d 10. 784-925? (925-1009 too small?), cf. Clark d 4. at 317 with this at 320. Does the shattering shown have something to do with the accumulation of the copper

36. Melaphyre (28) (640)

Amygdaloid d 2. 360-374
Cf. Medora d 10. 1098.
Trap d 2. 374-392
Very probably not an independent flow.

[2] A dip of 45° would make other distances correlate much better, and is probable.

37. Feldspathic doleritic ophite (87) (727)

Amygdaloid d 2. 392-399
Trap d 2. 399-491

The amygdaloid seems to dip at 14° to 18°, but the dolerite and other seams in the trap at 22.5° to 45°.

Cf. Mandan d 10. 1149-1220. Clark d 4. 388-

The distance from this, the top of the Kearsarge, to the "Osceola"? hanging (31) is about 407 feet which is small either compared with the Mandan or the Clark-Montreal sections. The large ophite 35, a persistent bed, is not as thick as its mottling would lead us to expect, but it is seamed and presumably some is cut out.

38. Kearsarge conglomerate (17)

Conglomerate and red sandstone d 2. 491-510 = 19

The apparent dip is 20° (744)

Cf. Fig. 29, M d 3. 4. S 121. While this thickness is much less than in the adjacent sections, it would take a dip of only 37.5° to make the thickness between the Calumet and the Kearsarge conglomerate the same as at the Manitou, and there are some independent reasons for believing this likely.

39. Feldspathic melaphyre (119)

Trap d 2. 510-517
Amygdaloidal trap d 2. 517-527
Trap d 2. 527-619

A brecciated vein at 551, faintly ophitic and feldspathic 558-610.

40. Melaphyre d 2. (37)

Amygdaloid d 2. 619-630
Trap d 2. 630-656
From d 2. 645-656 specked and weathered.

41. Sediment

Sedimentary breccia 656-658 under well-marked contact at 656. At 686 there is a red clasolite making an angle of 20° with core, evidently filling a nearly vertical fissure extending down from this bed?

42. Doleritic ophite (162)

Trap d 2. 658-820

Coarse d 2. 701-807, then a big fissure with reddened and apparently finer trap to the end.

43. Epidotic sandstone.

Yellow epidotic sandstone d 2. 820-824
Cf. Fig. 29, M 3. 4. S. 324, Central mine 50[a]

44. Ophite

Trap d 2. 824-854
Epidotic, much fissured.

45. Amygdaloid d 2. 854-856

Coarse
Trap d 2. 856-881
Fissured near d 2. 874, mottles 2 mm.

46. Amygdaloid d 2. 881-885

Red and white passing into a glomeroporphyrite.
Trap d 2. 885-971

Coarse, at first amygdaloidal, then seamed feldspathic, toward the base finer, reddened with laumontite seams.

[a] Under the Kearsarge conglomerate some ways a tendency to clasolitic occurrences and feldspathic traps is well-marked. Cf. also Arcadian No. 76, a lower horizon.

47. Ophite
Amygdaloid d 2. 971-978
Prehnitic coarse.
Trap d 2. 978-1032 At 1012 4 mm. mottles.
48. Amygdaloid d 2. 1032-1043
Red and yellow with trappy seams.
Amygdaloidal trap d 2. 1043-1060
49. Amygdaloid d 2. 1060-1069
Trap d 2. 1069-1091 (455)
Seamed and coarsest about d 2. 1081-6
50. Ophite (160+) ? (615)
Amygdaloid? d 2. 1091-1096
Trap d 2. 1096-1144+ (1023)

Mottling is 4 mm. at the end. This heavy ophite might be the bed in which Empire Hole 5 begins and if not, the dip is over 39°. If it is the same bed the dip is 38½° and at this dip its top below the base of the Kearsarge conglomerate would be (1091-510) 38½°, 455 feet. It can not be any lower bed in No. 5, as we can find no heavier bed in No. 2 with which to correlate the heavy bed at the top of Hole 5. A steeper dip would make this bed still nearer the Kearsarge conglomerate. At 45° for instance, the top would be only 350 feet below the same. At the Clark the only bed to connect with the top of Empire Hole 5 is that at the top of Clark Hole 2, 296-676 feet below the Kearsarge there. This is, I think, less than 100 feet from the Kearsarge amygdaloid.

Empire drill hole 5. 5200 feet south of datum 1500 feet S. of Hole 2. 270 above Lake Superior. Dip 90°.

The dip of the beds is uncertain but there is no probable correlation with Hole 2 that will give less than 38.5°. The apparent dip of the conglomerate at 765 feet is 45°. The mean rate of increase of grain in the ophite below appears to be not over 1 mm. in 25 feet or less whereas it is usually 1 mm. in 10 to 15 feet, which would suggest even steeper dips. In that case the Kearsarge amygdaloid and Wolverine sandstone lie in an unexplored gap between Holes 2 and 5.

Surface (28)
(50) Ophite
Trap d 5. 28-156
The mottles are respectively 7, 10, and 5 mm.
at 30, 60, 107 feet. (615?)
51. Ophite 579, (400±)
Amygdaloid d 5. 136-151
Trap d 5. 151-715

Marked brecciated amygdaloid, with a much disturbed amygdaloid trap just under, spotted to 174. The mottles are respectively
9, 15, 10–15, 5–10, 8, 3+, 1 to 2, 1 mm. at
239, 370, 415, –454, 536, 575, 629, 686.
There are doleritic seams between 250-284 and at 300, a big prehnite seam between 454 and 497, numerous joints crossing the cores at 45° from 629 on. Cf. Medora d 6. 239-649 (12mm.) and also Manitou d 7. 5. S. 54-333 with a little sediment at the base and 10 mm. mottles

also, another heavy ophite 333-552 just below. Cf. also Central mine 58. d 2. 442-498 = d 8. 42-314 with 59 & 60 sediment just below, and 311 feet below the Wolverine, and 12 mm. mottles. See also Arcadian Belt 68. Hole 2. 315′-464′+ (10 mm. mottles) Calumet and Hecla A. 193-273. This is uncertain. The prismatic augite form is often marked.

52. Conglomerate d 5. 715-720 5 1020

There is some felsite, but it is mainly amygdaloid conglomerate, much sheared, so that it is hard to tell shearing from dip—about 45°. This and the big trap above it would seem to match the Medora d 6. 652-657 best in position and association. Cf. also Manitou d 7. 5. S 333, and Franklin Jr. d 3. 535. The actual distance from d 2. 510 to d 5. 720 is 1513 feet, the thickness will vary according to the dip assumed; at 45° it will be 1215 feet at 38.5° 1100 feet at
29° 920 feet.

D 6. 657 is below the Kearsarge conglomerate at the Medora 1056 ft. Cf. Arcadian (76), as well as (69) which is (866+355) (1221) feet below the Kearsarge conglomerate.

53. Ophite
Amygdaloid d 6. 720?-724
Trap d 6. 724-789
The mottling reaches 5 mm.

This Empire cross section will cover just about the first mile south of the Allouez conglomerate (15), and should also show beside the beds of Section 14 those of the first row of forties in Section 23, leaving about half a mile to be explored down to the Mt. Houghton and the Bohemia conglomerate.

In this the dips will be steep, and they should be, for we have all the beds of Manitou-Frontenac 7, Holes 6, 7, 8 and 9, 2000 feet or so, to be crowded in, including the Isle Royale lode. (2300÷2640 = sin 60°)

§ 4. MANDAN[1] AND MENDOTA. (Figs 25 and 26.)

On Section 16 a couple of veins are indicated running into the Washington Copper Company lands, and on Section 17 on the east side are the fissures opened up by the Medora shaft of the Keweenaw Copper Company. Only a few belts just below the Allouez conglomerate have been proved up thus.

A much more complete section than any heretofore is that of the Mandan. This follows and is derived from notes of A. C. Lane and those of W. W. Stockly and A. H. Sawyer. This also runs north and south and the main section is close to the west line of Section 17, T. 58 N., R. 29 W.

Shortly east is a vein causing some displacement, shown by the drill records. On the coast east of Agate Harbor about 400 paces east of the west line is a vein striking nearly north and south,

[1]Developed at the same time as the Medora and so referred to at times in my notes.

called by Whitney the Giraffe vein. It would be hardly a stretch of the imagination to connect this clear across the range with the Mendota vein of Mt. Bohemia[2] in Section 29, six miles south, and there would be but a slight bend needed. However, I think it quite as likely that there is a sharp displacement of it on a strike fault or slide somewhere near the Montreal River just as the vein of the Central mine is displaced under the Kearsarge conglomerate.[3] Note the slide indicated in the section in Hole 4 at about 337 feet depth.

Mandan (Fig. 25 in envelope). Nearly N. and S. at right angles to strike. Mandan drill hole 14. Elevation 674.25. Surface 2 feet.

(19)[4] (1) The Greenstone.

Trap d 1. -578

Trap not exposed, mottles much of the way too large for the drill core to show distinctly. Manitou b. 19.

At 2, 95, 100, 125, 156–182, 182–224,
20 mm., 25 mm., 35, 28–32, 40+, 30+,
329, 363
22, 20
- at 474, 497, 513–521, 542–554, 568 ft. mottles are:
+ 8, 6, 5–6, 4, 1–1/2 mm.+

At 18 is a seam with copper and prehnite, at 408 is a seam of prehnite at 72° to the core, at 454 at 69°. At 29 and 33 it is doleritic with feldspar 3 or 4 x 2 mm. and augite in large grains.

The core owing to the uneven hardness due to the augite crystals has a peculiar knobby appearance well shown at 95 ft. Porphyritic crystals of feldspar occur (but are rare) and may be as much as 10 x 2 mm. or 12 x 7 mm. at 189 ft.

This also is the first bed in Hole 13 to 202 feet. In the interior of the augite the feldspar is smaller and by patches of smaller feldspar with coarser between them is the ophite pattern brought out.

At 13, 95, 128, 138, 143, 151, 158, 168 to 170,
the mottles are:
10–12 8, 7, 6, 6–5, 5, 4, 2–3 mm.
and at 177, 182, 187, feet they are:
½ to 1–½, 1 mm.

The rate of increase of diameter of the augite patches (A of Chapter IV) is one of the most rapid found—1 mm. in 8.5 feet, in 2.6 meters or .00032[5]

(20) (2) Allouez conglomerate

Absent in No. 14

in No. 13 202-220

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[2]See report by F. E. Wright for 1908.

[3]Hubbard, Lake Superior Mining Institute, 1895, Pls. II and III.

[4]The side numbers in parenthesis in holes 14 and 12 refer to corresponding belts in Manitou 3.

[5]Cf. the results in Manitou 3 and on Isle Royale. The fact that the gradient is greater here may be connected with the fact that it is thicker. But it must be remembered that with large poikilitic patches of augite one would think one would oftener get small clipped off segments of the patches and so get the grain too small.

(21) (3) Feldspathic ophite (13) 220-326
Amygdaloid d 14. 578-593 (14) (35)
with copper
Trap d 14. 593-616
Feldspathic ophite, amygdaloidal at top to 546 then finer and darker.

(22) (4) Feldspathic ophite. Hanging of Medora lode
Amygdaloid d 14. 616-621 (5) (53.)
Well-marked with calcite and pink and green amygdules
Trap d 14. 621-673 (48)
Feldspathic and coarsely amygdaloid at top, dark, finer, more chloritic at base.

Base below base of Allouez (87)
This corresponds to the distance to the Medora lode from the Allouez in the 7th level cross-cut in the Keweenaw Copper Co. mine on the Medora location, though there and in d. 13 but one flow occurs.

(23) (5) Medora lode and foot, feldspathic ophite
Amygdaloid d 14. 673-676 (3)
Well-marked with datolite and copper at 675 ft.
Trap d 14. 676-725 (45)
Faintly ophitic; at d 14. 700 seams at 45° to the core.
Distance from base of Greenstone 725-578 = 147 (136) ft.

(24) (6) Ophite, the Mandan ophite 60+
Amygdaloid d 14. 725-727 (?)
With copper (Manitou lode?)
Trap d 14. 727-860+ (132)
At d 14. 860 6-7 mm. which would indicate 60 ft. more at least. This I take to be the same as the heavy bed at the top of Mandan No. 1 to 120 ft, and No. 12, 20 to 511 feet, with a dip to be inferred of 20°. But the dip at the mine being 23.5° it is a question if this not due to faulting.
The distance in No. 14 is (136) between Greenstone and this ophite in No. 13 is (126)
Comparing various sections and exposures it seems that there are below base of Allouez to base of Mandan ophite (611)

Mandan drill hole 12. Is considerably to one side of main line of section and is thrown by a fault probably.

(19) The Greenstone ophite trap d 13. 0-202 (730+)
Described in connection with Hole 14

(20) Allouez conglomerate d 13. 202-220 (17)
Absent in d 14. Dip 18.5° in a sandy streak.

(21) Medora lode hanging (85)
and Amygdaloid d 13. 220-228 (7)
(22) Poor to d 13. 228, then brecciated, with copper and prehnite; much very fine copper to 225
Trap d 13. 228-310 (78)
Doleritic at 256 ft.
Basal amygdaloid d 13. 310-317

With Thomsonite in coarse scattered amygdules and amygdaloid spots included in Medora lode.

(23) Medora lode and foot. Strike N 87° 30′ E; dip 23° 40′ (21)

Amygdaloid d 13. 317-331 (14), (10+ in the mine)

Amygdaloid trap d 13. 331-338 (7)

(24) Amygdaloid d 13. 338-343 (5)

Trap d 13. 343-352-½

Holes 12, 2, 5, 1, 7, 9, and 3 around the Mandan overlap a good deal.

As near as I can make it the following is the correspondence

Houghton			Montreal		
(8) Cong.	(10)	(12)	(12)		
12.530–548	12.590–599	12.670–682	12.743–752		
1.121–124	1.185–196	1.263–277	1.350–359	1.480	1.901–920
3.120–128	2.112–128	2.191–200	2.277–304		
9.141–150	3.178–195	5.171–201	3.339–349	3.461	3.881–901
	9.210–223	9.282–305	5.280–290		10.177–194

Holes 7 and 9 have been thrown north 90 ft., i. e. the west side is thrown N.

There appear to be at this horizon (that of the Houghton conglomerate) three or four flows which are very similar, all having a well-marked ophite texture with amygdaloids which on top verge into an amygdaloidal conglomerate. See Plate VII, Sp. 20485. If the Houghton conglomerate is the top of the series, the lode opened on the Manitou property known as the Montreal lode appears to be this third. It was, however, enriched apparently only in the spot near a fissure.

Mandan hole 11 was merely to bed rock.

Mandan hole 12 vertical. Dip 22°.

(24) (5) Medora foote

Trap d 12. 2-20

Fine grained.

(27 to 28) (6) Mandan ophite (475)

Amygdaloid d 12. 20-33

Ill marked; contact also at 28 ?

Trap d 12. 33-511 = 478 (462)

Feldspathic ophite, at 70, 89-127 ft. the mottles are
3–5 7 mm.

Doleritic with 4 mm. feldspar at d 12. 136-137

Up to 10 mm. " at d 12. 192-193 with copper and coarse amygdules on a fine grained, red ground, another doleritic streak at 245-262 with 10 mm. feldspar. These streaks develop from normal ophite with no sharp contact. The augite patches continue coarse into them but the feldspar becomes much coarser, and more chloritic interstices form.

Chloritic seams at 89 are at 45° to the core.
at 239 are at 20.5° to the core.
at 386 and 439 at 69° to the core.

Toward the base they fall into a system parallel and perpendicular to the contact.

At 70, 89–127, 134, 164, 188–198, 213, 239–256, 284, 305, 328, 360, 386, 394, 439, 465, 478, 485, 495, 502, 506 ft. the mottles are 3–4, 7, 8 mm., 5–6, faint 7 mm., 1–2, 10–15, 15, 17-20, 20+, 13, 10–12, 12, 8, 5, 4, 4, 3, 2, 1 mm. a rate of increase = A about 1 mm. in 10 ft. (9.3) starting from 518 to 328. About 213 there is an irregularity that suggests close welding of two flows, or faulting, or possibly super-heating and hence finer grain.

In the coarseness of the mottling this is next to the Greenstone, and one might even think of repetition by faulting. In no other section is there nearly as heavy a flow here.

See Mandan Hole 1 down to 121, Hole 9. 10 to 282

Base of Mandan ophite below base of Allouez (637 ft.)

(7) Melaphyre

Amygdaloid d 12. 511-515 (4)

Trap d 12. 515-530 (14)

Fine grained. This does not appear in Holes 9 and 1

(32) 8. Houghton conglomerate ?

Conglomerate d 12. 530-542 (12?) elsewhere (3)
9. 141-150
1. 121-124?
Cf. also 1. 181-195

Base of Houghton conglomerate to base of Allouez (666)

This checks very well with the thickness at the Manitou but the section between does not compare well.

(33) 9. Feldspathic ophite. (48)

Trap d 12. 542-590 (48)
9. 150-185 to 210
1. 124-185

Brecciated and amygdaloidal to 554, lightly glomeroporphyritic to 559; an amygdaloid spot at 585.

10. Amygdaloid conglomerate top.

Amygdaloid d 12. 590-599
9. 210-211
1. 185-196

Brecciated to 592 and from 594-599 appears to be a conglomerate.

11. Ophite (3 mm.)

Trap d 12. 599-670 (66)

At 605, 610, 618, 634, 647, 651, 655, 656, 661 ft. the mottles are ½, 1, 2, 3, 2, 1–2, 1½, 1, ½ mm.

From 661 ft. to 670 ft the trap is brecciated, the core in nubbins.

Same 3 mm. coarseness also in Holes 9 and 1.

12. Amygdaloid conglomerate?
Amygdaloid d 12. 670-682 (17)
9. 282-300
1. 263-277
2. 191-200
3. 265-275
brecciated with green and red fragments, to 682 poor.

13. Ophite
Trap d 12. 688-743 (51)
At 688, 693, 700, 712, 715, 723, 733 ft. the mottles are 1, 1–2, 1 and 2, 2, 3, 2–3, 1–2 mm.
Chlorite seams at 723 at angle of 51°.

(38) 14. Ophite "Montreal lode" (3 mm.+) (48+)
Amygdaloid d 12. 743-757
9. 365-380
1. 350-359
2. 277-304
3. 339-349
5. 280-290
Green and red fragments of amygdaloid and trap mixed.
Trap d 12. 757-791+ end of hole
At d 12. 781 and 791+ feet the mottles are
1–2 and 3 mm. respectively

Mandan drill hole 1. About 100 ft. east of the west line and 610 ft. north of the W. Q. P. of Section 17, T. 58 N., R. 30 W., about 700 feet from the quarterpost in direct line and about 1460 feet south of the Greenstone (the Allouez conglomerate No. 15) elevation 380 A. L. There is a coarse outcrop of Mandan ophite about 100 feet north of it. The greenstone base is said to be 1460 feet north and by my measurement a point where the mottles are 3-5 mm. across is about 1290 feet north on a level. It must begin then between 530 and 630 feet below the Allouez, probably 680 feet. The reduction factor for the thickness is about 89°.

1. Overburden (hardpan till) 7
6. Mandan ophite (200?)

Trap d 1. 7-120.6 = 113 (92)
Lower half or third of a heavy ophite begins with 10-12 mm. mottles at 7 feet, and apparently equally coarse to 34 feet; at
57, 83, 99, 109 feet, that is —
52, 30, 17½, 9, feet from the bottom.
the mottles are reduced to
8-10, 4 + mm., 4 mm., 2 mm., across. We have some feldspars, minute brown specks of altered olivine (rubellan) and chloritic seams or joints making angles of
21°, 29°, 32°, 22°, with the drill core at
43′9″, 50′, 58 to 85 , feet respectively
probably about at right angles to the dip; averaging these observations would be 26°, while the dip appears to be 28°.

7. Sediment ? d 1. 120-124 = 4 (4)

Houghton conglomerate?

d 1. 120-122 is greenish white, epidotic and sericitic. At 124 feet there is a pink and green mottling like Castile soap and an apparent dip of (8:15) 28°. This may be the beginning of the Houghton conglomerate horizon but no where else do we seem to have an extra heavy bed *just* above.

This Mandan Ophite is a very heavy bed and from the grain I could hardly have put it down as less than 250 feet thick. It ought accordingly to be fairly persistent. We find one in the Franklin Jr. under the Albany and Boston conglomerate 15, from 100-233 below, the Houghton being 389, two flows intervening.

No. 37 in Tamarack No. 5, belts 59-60 from 3320-3594 is a massive ophite 217 feet thick, which we find in the other shafts:

In Tamarack No. 4 from 3050-3334, 234 feet thick.

In Tamarack No. 3 from 2819-3114, 225 feet thick.

In the Redjacket shaft at 1954 and 2200, about 202 feet thick, its base about 455 below the Allouez.

At the Cliff an extra heavy bed of trap seems to be between 400 and 500 feet below the "slide".

At the Central, the nearest equivalent would seem to be (8) from 401-476 feet below the slide, noted as very thick and uniform, though the Central mine section is evidently taken so carefully as to give many pseudoamygdaloid and doleritic bands, probably not individual flow tops, elsewhere overlooked. It is taken near a vein where the belts are hard to make out. At the Delaware mine we find a heavy bed of trap from 100-360 feet below the Allouez which in the deeper levels of the mine is counted as two with an amygdaloid. But my studies at the surface show that it is probably all one bed, with a good many doleritic streaks and full of amygdaloid inclusions. It is probably these latter that lead it to be called two beds deeper down. Cf. Manitou d 3. 27 to 28.

There appear to be only two amygdaloids between this and the horizon which has been called No. 2 and has been identified by Marvine as the Houghton. This latter appears as a well-marked amygdaloid contact in an old railroad cut about 1230 feet from and 100 feet below the Allouez conglomerate, or over 600 feet below it.

9. Amygdaloidal melaphyre (53)

Brecciated amygdaloid	d 1.	124-129 = 5 (4)
Amygdaloidal trap	d 1.	129-163′6″ = 34 (30)
Trap	d 1.	163-185 = 22 (19)

Amygdaloid much veined but with pieces of red amygdaloid with amygdules in a flaky ground full of irregular seams of calcite which in a general way dip (8:15) at an angle of 28° and probably indicate the sliding. At 129′ 6″ it becomes hard brown, compact with very small white amygdules. There are then red fragments with calcite seams and blotches to 132, then a foot like 129′ 6″ fine grained with white specks crosswise, then a foot redder and more calcitic, then like 129 to 142, with brown specks of altered olivine; at 142-143 there is a rusty streak with amygdules still numerous; at 145 there are white amygdules 5 mm. across with chlorite rims, and calcite centers; it remains fine grained with scanty small amygdules to 163′ 6″ where it becomes

prehnitic. There is a laumontite seam at 161. At 164 it becomes more massive trap with 1-2 mm. mottles at 172, then fine grained and black.

10. *Scoriaceous amygdaloidal conglomerate* d 1. 185-191 = 6 (5)

d 1. 185-188 is a breccia of fine grained red amygdaloid with white amygdules and veins, and to 191 it is a well-marked scoriaceous conglomerate.

11. Ophite (3 mm.)

Amygdaloid d 1. 191-196 = 5 (4½)
Trap d 1. 196-263 = 67 (60)

The amygdaloid is poor and coarse, and probably if not shattered much of the belt above would belong to this amygdaloid. The trap has well-marked mottles:

2,	2-3,	2-3,	3,	1-2,	½ mm. at
205,	212,	217'6"	240,	248,	257 feet
(47)	(43),	(37),	(19),	(12),	(5) (feet from base)

The base of the flow is near 261 feet. From 261-263 is fine-grained amygdaloid.

12. Scoriaceous conglomerate d 1. 263-277 = 14 (12½) (840)

Includes also the broken up (brecciated) part of the beds below. This is the lowest place at which the Houghton conglomerate can come.

13. Ophite (3 mm.) (64) (904)

Amygdaloid d 1. 277-279 = 2 (2)
Trap d 1. 279-350 = 71 (2)

The amygdaloid contains calcite, prehnite and copper (possibly Montreal lode?). The trap has mottles 2 mm. and 3 mm. at 297, 307, 44, 35 feet respectively, then growing finer.

A fine grained ophite, with chloritic amygdules, from 345-350.

14. Ophite (Montreal lode and foot) 5-6 (114) (1018)

Amygdaloid d 1. 350-369 = 19 (17)
Trap d 1. 369-480 = 111 (96)

The amygdaloid is poor and but slightly brecciated to 359.

There is rather more trap to 365, then to 369 there is much prehnite and copper. Montreal lode ? The trap is at first rather broken up, but has well-marked mottles of

2 mm.,	3-4 mm.,	4-5 mm.,	5-6 mm.,	4 mm.,	2 mm.,	1 mm., at
376-380,	399,	409,	426,	442,	460,	469 ft
(871-8),	(67),	(58),	(44),	(31),	(17),	(8) above base.

There are numerous chlorite seams, making angles of 33° and 54° with the drill core. (At 456 is a speck of copper in one)

15. Ophite (3 mm.) (52) (1070)

Amygdaloid d 1. 480-482 = ? (2)
Trap d 1. 482-538 = 56 (50) ?

The amygdaloid is pure and the ophitic texture is at once resumed. We may probably infer no great break between.

The mottles are	1,	1-2,	3,	3,	1-2 mm.
at	483,	487,	501,	515,	527' 6" ft.
	45,	42,	31,	19,	8 above base

16. Amygdaloid conglomerate d 1. 538-545 (7)
d 3. 520-545
with copper, red, fine grained, brecciated with different kinds of amygdaloid.

17. Ophite
Trap d 1. 545-622 (73)
At 575, 594, 603, 606, 612, 619 feet the mottles are
1, 1–2, 2, 2, 1, ½ mm.

18. Ophite (1 mm.)
Amygdaloid d 1. 623-625 (2)
Prehnite and perhaps a sphere of Thomsonite.
Trap d 1. 625-648 (23)
Fine grained, with chloritic amygdules and very chloritic at base.

19. Amygdaloid conglomerate d 1. 648-668 (18)
With prehnite; at 668 a slickensided seam, so striated, (it dips 67.5° against core) that if the dip of the plane is really 22-½° to the north, the strike of the striae is about N. 18° E. This is in a way really the top of 20 and should be compared with d 3. 653.

20. Trap d 1. 668-679 (10) Melaphyre (10)?
Fine grained

21. Ophite 3 mm. (143)
Amygdaloid d 1. 679-681 (2)?
3. 653
Trap d 1. 681-835 (14)
Fine grained with amygdaloid spots to 700
Joints at 63° and 58°

	At 700,	706,	714,	722,	738,	755–9 ft.	
The mottles are	1–½,	2–3,	3,	4(7x3),	5,	7mm.	
790,	796,	801–4,	813,	821,	824,	828	
8,	6,	4–5,	3,	1,	1–2,	1 mm.	

19 to 21 may well be one flow. Cf. Manitou 42. Cf. Empire 24.

22. Ophite 3 mm.
Amygdaloid d 1. 835-839 = 4
Trap d 1. 839-901 = 62
From 850 distinctly coarser, and at 864 and 881 3 mm. across.
At 891 ½ mm. getting finer.

23. Conglomerate—the Calumet (18)
d 1. 901-920 = 10. 177-194 (19)
One inch felsite, the rest basic
Base below base of Houghton conglomerate
at 24° dip, about d 1. 920-124 = 796 × cos 24° (726)
or from d 12. 592-743 to Montreal lode hanging 201
from d 3. 339-901 thence to Calumet base 763 (710)
or from d 3. 120-901 781 (725)

Mandan drill hole 3. Laps Hole 1 almost all the way, as follows:

7. Trap d 3. 115-128
8. Houghton conglomerate absent

9. Ophite. (65)
Amygdaloidal trap d 3. 120-128 = 8
Trap d 3. 128-178 = 50
at 136-142, 142-152 feet the mottles are
1 1 to 2 mm.
Amygdaloid d 3. 178-190 = 12
Marked dark and white. This is apparently a basal amygdaloid.

10. Houghton conglomerate?
Amygdaloid conglomerates d 3. 190-195
d 1. 185-188
Marked with red sediment as well as decomposed matter and dark fragments.

11. Ophite (2-3) (64)
Amygdaloid d 3. 195-198 = 3
Poor, the balance in the bed above
Trap d 3. 198-265 = 67
At 208, 228, 240, 246-249 feet the mottles are
1 and 2, 2, 2-3, 1 to 2 mm.

12. Amygdaloid conglomerate d 3. 265-275 (9)
Well-marked with considerable sediment.

13. Ophite (2 ½ mm.)
Amygdaloid d 3. 275-282 = (7)
Brecciated trap d 3. 292-340 = 48
at 295, 303, 315, 320 feet the mottles are
1 to 2, 2 to 3, 2 to 3, 2 decreasing to base. Little thinner than in 1.

14. Ophite (4 mm.) (110)
Amygdaloid d 3. 340-348 = 8
Almost an amygdaloid conglomerate; Montreal lode ?
Trap d 3. 348-461 = 113
Fine grained to 378 ft. at 378, 394, 402, 423, 435,
1 to 2, 3 to 4, 4, 4, 3,
443, 455, 459,
2, 1, ½ mm.
There is probably some faulting disturbance near 378.

15. Ophite (2 mm.) (53)
Amygdaloid d 3. 461-465 = 4
Cf. d 12. 670
Brecciated at top
Trap d 3. 465-520 = 55
Fine grained to 407, then brecciated; in spots amygdaloidal; at 491, 2 mm. at 508 about ½ mm., like 459 exactly; 486 was a band of finer grained, 1-2 mm mottles.

16. Melaphyre (23)
Amygdaloid d 3. 520-535 = 15
d 1. 480
Trap d 3. 535-545 = 10
Brecciated, the Montreal lode being perhaps a shearing band.

17. Ophite 2 mm? (Montreal lode and hanging) (53)
Amygdaloid d 3. 545-575? = 30 with spots of breccia
Trap d 3. 575-603 = 28
Ophitic, coarsest is 1-2 mm., at 598 it is 1 mm. and 599 ½ mm.
Manitou d 6. 40 or 38?
Ophite 1 mm.

18. Amygdaloid d 3. 603-605 (45)
Poor d 1. 648?
Trap d 3. 605-607
Poor amygdaloid d 3. 607-612 5
Trap d 3. 612-653 (? or 643)

19. } Ophitic; at 620, 626, 631, 642 feet the mottling is
20. } ½, 1, 1, ½ mm. respectively
Manitou (41)?

21. Ophite (5 ½ mm.)
Amygdaloid d 3. 653-671 = 18
d 1.. 668 or 679
Brecciated.
Trap d 3. 671-812 ? = 141
Ophitic, at 692, 695, 703, 715, 730, the mottles are
2, 2, 2 to 3, 3 to 4, 5, mm.
at 750-760, 787, 798, 803, feet they are
5 to 6, 3, 2, 1, mm.

This extra heavy ophite, the second above the Calumet conglomerate, is also in the Manitou (b. 42, 167 feet thick). Central (cf. 24). Just above, too, in all cases there is a belt with only small mottles often considerably disturbed.

(22) Ophite 2 mm.
Amygdaloid d 3. 812-821-834-836 = 24

Poor with small amygdules, then trap, then poor again, to 834, then poor and coarse with calcite and prehnite to 836.

Trap d 3. 836?-881 = 45

At 863 2-3 mm. mottles. In No. 1 it is (61) feet thick with 3 mm. mottles. At the Manitou it was from 52-63 feet thick (644) and at the Empire it is similar.

(23) Calumet conglomerate, d 3. 881-901 (18)

At 881 a narrow band with small pebbles of felsite but mainly an amygdaloid conglomeratic with porphyritic, not very amygdaloid fragments, toward the base considerable red mud, with dips of 23 to 26.5°.

Cf. d 10. 177-194
d 1. 901-920

(24) Ophite
Trap d 3. 901-961
d 10. 194
at 913 to 920 the mottles are
1 to 2 mm.

(25) Ophite (1-2 mm. + ?)
Amygdaloid d 3. 961-971 ?
d 10. 245
Trap d 3. 971-1047 plus

At 1012 the grain is 1-2 mm. Between 1047 and 1073 there is a fine and a coarse streak, and much chlorite, cf. d 10. 294.

The line between (25) and (26) can not be made out.

(26) Ophite (4 mm. +)

Trap d 3. 1073 minus to 1095 plus

at 1073 and 1092 feet the mottles appear to be

2 to 4 mm. respectively.

There are numerous laumontite seams at 75° to core.

The grain at 1095, (171) feet below the Calumet, is about that in d 10 at 401, which is (186) feet below.

Mandan drill hole 7. Falls on the cross section at 5450, but the correlations are plainly such as to show it has been relatively displaced 90 feet to the N., being on the west side of the section. Vertical, elevation 494.51 above datum.

1. Overburden of drift (sand) 115 feet

13. Ophite 2-3 mm. (61+)

115 minus to 166

Trap at 115, 138, 160

1, 2-3, 1 mm.

Amygdaloid conglomerate ? 166-168

14. Ophite (5+) Montreal lode and foot

Amygdaloid and amygdaloid trap d 3. 168-185 (16) (120)

d 1. 350-359

Trap d 3. 185-297 (104)

At 188 are coarse and fine mottles 1 mm. to 3 mm. in alternate bands, with a few chloritic amygdules and a spot of amygdaloid at 190 and 195.

At 194, 204, 223, 235, 254 the mottles are]

2-3, 3, 4, 5, 5+ mm. then a chlorite seam, at 26°

then at 271, 277, 282, 287, 290 ft

3½, 2, 1 to 2 1, ½ mm.

The hole may cross a fault at 255, and the last ophite does not match 15 well.

15. Ophite

or 17. (50)

Amygdaloid d 3. 297-307 (9)

Red and white typical

Trap d 3. 307-351 (41)

Brecciated to 312 and amygdaloidal to 319

At 340 to 351 showing 1 to 2 mm. mottles.

Mandan drill hole 2 laps Hole 1 a short distance at the top giving a good chance to get the dip, 25°. Vertical elevation 510 above datum,— 410 A. L. S.

1. Drift 58

(9) 2. Amygdaloid d 2. 58-61 (12)

Decayed laumontite, with signs of sediment.

Trap d 2. 61-113 (47)

Chloritic, fine grained joints at 25° to core.

(10) 3. Amygdaloidal conglomerate (14)

d 2. 113-128

d 1. 185-196

Marked and sedimentary contact dip 18.5° to 24° fading from conglomerate to amygdaloid with small pink and white amygdules.

(11) 4. Ophite (2 mm.) (57)
Trap d 2. 128-191
Red brecciated and amygdaloidal at base
At 136, 142, 159, 165, 172 feet the mottles are
1 to 2, 2, 2, 2, 1½ mm.
(12 and) 5. Ophite (3 mm.) (90)
(13)
Amygdaloid d 2. 191-200 (8)
d 1. 263-277
Trap d 2. 200-277 (70)
At d 2. 215-217 nearly vertical seams
At d 2. 223, 227-245, 250, 264, 268 feet the mottles are
1 to 2, 2, 2, 1 to 2, 1 mm.
Basal amygdaloid 277-290 (12) joints at 59° and perpendicular.
(14) 6. Ophite (3½+ mm.) Montreal lode (62+35+)
Amygdaloid d 2. 290-304
With laumontite, calcite, chlorite
Traps d 2. 304, 347
At 308, 321, 332, 342 ft.
1 to 2, 3, 3, 3½ mm. mottles

Mandan drill hole 10. At 4353 of section, vertical. Correlating with the Calumet and Hecla conglomerate in No. 1 gives a dip of 26.5° and a reduction factor of .90
1. 27 feet of drift
(21) 2. Ophite (6+) (80+40?)
Trap d 10. 27-117
At d 10. 32, 63½, 70, 100, 105, 114 the mottles are
4, 6½, 5½, 2½, 1, ½ mm.
Then there are chlorite seams at 24.5° and 42" at 114 ft.
This is evidently the lower part of flow 21, i. e. d 1. 679-683
d 3. 653-750
(22) 3. Ophite (54)
Amygdaloid d 10. 117-139 (20)
d 1. 835
Poor, fine grained, red, porphyritic
Trap d 10. 139-177 (34)
d 1. 839-901
At 145, 157, 170, 175 feet the mottles are
1 to 2, coarser 2 1½
At 146 it is brecciated and the samples sludge, as also at base. The bed is evidently disturbed.
(23) 4. Calumet conglomerate Marvine's 13 d 10. 177-194 (13)
1. 901-920
3. 881-901
The top is brecciated and ill-defined from the amygdaloid above but passes into a distinct basic conglomerate with red sediment and crystals in the cavities.
(24) Ophite 2 mm. (46)
d 10. 194-245 to (40)
At d 10. 217 feet the mottles are 2 mm.
I doubt if this is present in the Manitou section.

25. Ophite 2-3 mm. to (90)
Amygdaloid d 10. 245-259 (13) (78)
3.961
Amygdaloidal trap d 10. 259-265 (8)
with large amygdules
Trap d 10. 265-331 (59)
At 266 to 273, 278, 285 to 296, 306, 327 ft.
1, 1 to 2, 2 to 3, 2 to 3 finer, 1 to 2 mm.
At 294 ft. a seam at 45°
This would agree well with Manitou 45 M. 3. 2. S 100-172, M. 7. 1. S. 260-320
Amygdaloid d 10. 321-345 (14)
Fine red and white brecciated, its relations with the ophite above and the conglomerate below uncertain.

26. Amygdaloid conglomerate d 10. 345-351 (5)
Beds 26 and 27 may be d 6. 46 of the Manitou section.

27. Ophite (4 mm.) (73 to 64)
Trap d 10. 351-433
At 357, 362, 381, 396, 401, 408, 418, 422, 429
1, 2, 2 to 3, 3, 4, 2 to 3, 2, 1, ½

28. Ophite (5 mm.) (120)
Amygdaloid d 10. 433-450 (15)
Trap d 10. 450-567 (105) (to 105)
At 450, 457, 468, 488, 497, 505, 530,
½ to 1, 1, 2, 3, 2 to 3, 4 to 5, 4,
543, 547, 551, 565 ft
3 to 4, 2 to 3, 1 to 2, 1 mm.
This agrees best with the 5 mm. ophite 6.47 of Manitou section.

29. Ophite (6 mm.) (115)
Amygdaloid d 10. 567-582 (13) to
Typical red brecciated with amygdules (100)
Trap d 10. 582-694 (101)
At 616, 619, 624, 629, 639, 660,
1, 1 to 2, 2 to 3, 3, 5 (6 maximum) 5,
At 665, 667. 682, 683, 688, 692 feet mottles are
3 to 4, 2 to 3, 2, 1 to 2, 1, ½ mm.
At 677 is a heavy chlorite slip dipping 80.5°.
This agrees in grain and thickness fairly, with b. 48 of the Manitou section, supposed to be above the Calumet amygdaloids there.

30. Ophite (3 mm.) Calumet amygdaloid and foot (81)
Amygdaloid d 10. 694-700 (5)
At 698 is a phenocryst ?
Trap d 10. 700-784 (76)
At 715, 732, 737, 743, 780 feet the mottles are
1 to 2, 2, 3, 1 to 2, ½ mm.
At 758 and 763 there are amygdaloid streaks. Cf. Manitou 49 M. 3. 2. S., 459-545 also cf. 50. Doleritic. In calling this the Calumet amygdaloid there is a possible error of one flow each way.

31. Ophite (5 mm.) Osceola amygdaloid (128)
Amygdaloid d 10. 784-788 (4)
Red, fine grained, poor
Amygdaloidal trap d 10. 788-793 (4)

Trap d 10. 793-926 (120)
At 796, 801, 814 to 822, 825, 842, 862 ft.
1 to 2, 2, 3, 4, 4, 5 mm. then finer

The grain seems rather fine for the size. Quite likely the dip is steeper (over 31°) and the reduction factor greater.

At 828 ft. is a doleritic spot with 3 mm. feldspar
At 831 ft. " " " " " 3 mm. "
These doleritic streaks remind one of Manitou Belt 51.

Frontenac 3 d. 3 S. 172-325. In this case the correlations in Manitou 3 d. 3 S. and Frontenac 3 d. 3 S. and 49 and 50 are identical.

32. Feldspathic ophite?

Amygdaloid d 10. 925-929 (4) (658)
Prehnitic, brecciated (76)
Amygdaloidal trap d 10. 929-1009 72
Flow lines, apparently at 39° dip, coarse chloritic and prehnitic.
At 971, 982, 998 feet the mottles are
2, 4 to 5, 2 to 3 mm.

The mottling is abnormal at the base and not visible above; often so in the feldspathic beds.

33. Feldspathic melaphyre (36)
Amygdaloid d 10. 1009-1012 (3)
Trap d 10. 1012-1049 (33)

Slightly amygdaloidal with coarse amygdules, feldspathic and fairly mottled at first. At 1023 2-3 mm. mottles; at 1031 seams at 50°; at 1042 appears finer, at 1044, however, 2-3 mm?

Manitou 54 seems to include or replace this whole feldspathic group.

34. Amygdaloid d 10. 1049-1052 (3) (13)
Trap d 10. 1052-1063 (10)
At d 10. 1054 2 mm. mottles

35. Melaphyre (50)
Amygdaloid d 10. 1063-1105 = 42 (38)
Amygdaloidal trap d 10. 1105-1118 (12)

A good many scattered amygdules, some with datolite at 1114; a prehnite copper seam is nearly vertical 85°.

36. Amygdaloid d 10. 1118-1120 (2) (28)
Fine grained, no well-defined contact
Trap d 10. 1120-1149 (26)
At d 10. 1129 2-3 mm. mottles.

37. Feldspathic ophite (19)
Amygdaloid ? d 10. 1149-1152 (3)
A fine grained green seam with prehnite and copper
Trap d 10. 1152-1170
At d 10. 1160 faint 2-3 mm. mottles (45)

38. Ophite (3 mm.)
Fault band and spots; no marked amygdaloid d 10. 1170-1177 (6)
Trap d 10. 1177-1220 (39)
Ophitic at 1188, 1193, 1210
2 to 3, 3, 2 mm.
Manitou 55

Distance from base of Calumet conglomerate, (1220-194) × cos dip is 900 ± 20 feet according to the dip assumed.

As in 8 there is a heavy bed above the Kearsarge and this is true elsewhere and as the distance up to the Calumet is short, it is quite likely that a fault has cut out part of this bed

39. Kearsarge conglomerate (9)

Sandstone and conglomerate d 10. 1220-1230+
d 8. 167-177

from 1228 to 1230 a regular mud with a dip of 30⅓- the best. Other dip observations are 30°, 31°, 36⅔°, 25.5°.

Correlation with No. 8 also gives 31¾°. The observations on the core show that this steeper dip is real, not apparent and merely due to faulting.

This is Manitou No. 56.

As the distance to the Calumet conglomerate is a good deal less here than at the Manitou and Central it seems best in Hole 10 to use the dip to Hole 1, 26.5° and the less reduction factor, though no doubt the dip really increases to about 30°.

Mandan drill hole 8 at 26 + 32. Elevation 3.78 vertical. Dip (31¾ to 27½) about 30°. Reduction factor .86. The dips and seams and joints in the hole indicate an even greater dip near 39°.

"Overburden" drift, sand (48)

Feldspathic ophite (92)

Trap d 8. 48-15+

At 75 feet 5 mm? mottles faint but coarser.

At 115 2 inches of clay fluccan, mottles about as coarse, then grows finer with seams dipping 34°, brecciated at 154.

38? Melaphyre (8)

Amygdaloid d 8. 158-160

Amygdaloid trap d 8. 160-167

This may be merely a foot.

These beds do not at all match the section above the Kearsarge in d 10 except in their general character as feldspathic ophites. Really, however, Belts 33-39 in that hole are all ill-defined and so are they here, and in Manitou Belts 54 and 55.

39. Kearsarge conglomerate (9)

Felsitic conglomerate

d 8. 167-177

Dips 38½, 38½, 41½

Doleritic feldspathic ophite (133+)
or

40. Ophite (163)

Bleached amygdaloidal trap, passing into

Mottled trap 177-331-519

at 194-197, 280, 331 feet the mottles are
2-3, 5? finer, then there is a curious coarse amygdaloid, not an ordinary top, but quite likely separating close succeeding gushes. At 454-499 the mottles are 5 mm.-3 mm. and then it grows finer and darker-chloritic.

At 200 seamed perpendicular, at 212 at 30° dip, at 331 35° and vertical or 69° and 45° seams at 33° parallel to bedding?

Doleritic with coarse feldspar and amygdaloidal at 260, 262, 387, 388, 392 to 4, 403 to 5, 409 to 410 with 5 mm. feldspar and blotches of chlorite, 426.

This is probably Manitou Belts 57 and 58 (296)

41. Feldspathic melaphyre (25)

Amygdaloid d 8. 519-523 (3)

There is a distinct contact here, and below it is red glomeroporphyritic with sparse amygdules of prehnite.

Trap d 8. 523-548 (25)

Faintly mottled at 528-542 (2 mm?) Perhaps this faint coarse mottling is due to feldspar aggregates, glomeroporphyritic.

42. Feldspathic melaphyre

Amygdaloid d 8. 548-559 (10)

Glomeroporphyritic coarse amygdules (24)

Trap d 8. 559-573 (12)

Glomeroporphyritic finer

Basal amygdaloid d 8. 573-574.5 (2)

43. Sediment at d 8. 574.5

(Cf. the sediment in Manitou Beds 59 to 64)

44. Melaphyre d 8. 574.5.-585 (8)

Fine grained

45. Sediment at 585 ft. below Kearsarge conglomerate 353

46. Feldspathic ophite (71)

Amygdaloid d 8. 585-589 (3)

Trap d 8. 589-667 (68)

At d 8. 635 2 mm. mottle, seam at 39½

Cf. Mandan 63, the top of which is 258 feet below the Kearsarge. A steeper dip here would make a better agreement.

47. Feldspathic ophite (40)

Fine grained top Mandan d 8. 667-672 (4)

Red glomeroporphyritic, only slightly amygdaloid

Trap d 8. 672-713 (35)

Perpendicular seams at 687

At 692 and 712 is a 2 to 3 respectively 1 to 2 mm. faint mottling.

48. Feldspathic ophite (60)

Amygdaloid d 8. 713-716 (3)

Fine grained with prehnite and copper

Trap d 8. 716-782 (56)

Seam at 26.5°. Toward base is darker and mottled, at 753 3 mm.

49. Feldspathic ophite (62)

Amygdaloid d 8. 782-790 (7)

Fine grained, red with coarse chloritic amygdules.

Trap d 8. 790-853 (55)

At 818 and 825 ft. the mottles are 2 to 5 and 2 mm.

The base is also red and porphyritic.

(25)

50. Amygdaloid d 8. 853-871 (15)

Red and pink or white laumontite, at top; toward base prehnite or thomsonite and slightly amygdaloid.

Trap d 8. 871-882 (10)

51. Sediment at 882 (marked contact)

Base below base of Kearsarge (611)

Cf. Manitou b 67 which is 178 ft. above the Kearsarge lode and Central 650.

52. Melaphyre. (25)

Amygdaloid d 8. 882-888

Coarse, poor

Trap d 8. 888-end

Cf. Manitou b. 68

Owing to the unexpected steepening of the dip this hole does not quite lap No. 6. Assuming that Belt 51 is 178 feet above the top of the Kearsarge lode, as at the Manitou, the dip from 6 would be 31¾° and all indications are that the dip is at least as steep as that.[6]

The total distances from the Kearsarge lode up to the Kearsarge conglomerate would be about 775 to 789 feet, of which perhaps 88 feet are unrepresented and must be filled in with the aid of the Manitou sections.

If the total distance from base of the Kearsarge conglomerate to top of the Kearsarge amygdaloid is only 724 feet as in the Manitou 3 section there will be but 29 feet unrepresented. If the dip is steeper[6], then Manitou Belts 70 and 71 may be unrepresented as 71 certainly is.

53. Sediment Manitou, Cf. 71 unrepresented at (636?)

Mandan drill hole 6. 50 feet south of Montreal River, see Fig. 25. Elevation 439.31 above Lake Superior. Vertical. Overburden drift. (636) (52)

54. Feldspathic ophite (26+20)

Trap d 6. 52-82 begins faintly mottled grows finer, at 692, 3 mm.

Cf. Manitou 6. 69 and 70

55. Melaphyre (18)

Trap d 6. 82-106

Fine grained with a little poor amygdaloid top.

Cf. Manitou d 6. 72 which may include 53 also

56. Ophite hanging of Kearsarge lode (38)

Amygdaloid d 6. 106-112 (5) with red amygdules and white pink bordered ones.

The amygdaloid looks something like the Kearsarge.

Trap d 6. 112-150 (33)

Faintly mottled cf. Manitou 73 Frontenac 3. 5. S. 235-238

This will be No. 53 of the Central mine section

No. 73 of the Manitou 3 section

Base top of Keweenaw lode below base of conglomerate as estimated implying a dip of 30° 732

Cf. 724 feet at Manitou 3 724

57. Kearsarge lode and porphyritic ophite foot

Amygdaloid d 6. 150-156 (5)

With pink bordered amygdules so common in the Kearsarge lode and porphyritic crystals.

Trap d 6. 156-220 (55)

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[6]Later drilling (No. 16) shows that this is so, and indicates dips as steep as 46°.

The porphyritic crystals are up to 10 or 15 mm. x 2 or 3 mm. at the beginning; at 168 appear a little coarser 25x5.

At 180,	200,	208,	feet the mottles are
2–3,	2,	1-½ mm.	

At base chloritic and numerous other seams.

In Mandan Hole 17. 28 or 62-105, the figure 62 being the lower amygdaloid in 18.51? or 84-135-½
in 19.35-89 (54) at a 60° dip, the hole beginning in amygdaloid.

Comparison of the thicknesses in the vertical hole and those at 60° would indicate a dip of 42°.

58. Wolverine sandstone. Marvine's No. 9 (9)

Sandstone passing into amygdaloid conglomerate d 6. 221-231 Dips noted were 55° (cross-bedding) 29.5°, 35°, 34° and 32°. Such a dip would imply a thickness of about 863 feet, from the base to the base of the Kearsarge, as against 982 at the Manitou and 752 at the Central.

Such a dip, proportionally greater thickness of section, and less thickness of individual beds is quite likely and has since been shown.

(801)

Central mine b.56
Manitou b. 78

59. Melaphyre (?) (7)

Trap 6. 231-239
Manitou b. 79 ?

60. Ophite 12 mm. (345?)

Amygdaloid d 6. 239-251 (10) (to 280)
With a clasolite in crack showing bedding at 45° dip (295)
The amygdaloid contact dips 28.5°.
Trap d 6. 251-649 (335)
The mottling is well-marked.

At 254,	267,	275,	281,	302,	314,	330,	340 ft.
2,	3,	3,	3 to 4,	5 to 6,	6,	7,	8,
359,	378,	393 ft.					
9,	10,	12 mm.					
At 400,	414,	430,	441,	457,	494,	524,	543,
12,	10,	9,	11?	7?	8,	7,	5mm.
547,	565,	584 to 586,	593,	602,	607,	609,	619,
4⅔,	3,	2,	2,	1½,	1,	1 to 2,	1½ mm.
632,	645						
½	⅓ mm.						

The extra slow rate of increase in grain in what appears to be a normal ophite suggests that the bed is cut quite obliquely. This is presumably Central mine 58, occuring in Holes 2 and 8, 42-314. The rate of increase there is about 1 mm. in (10) feet thickness from the bottom, but here it is 1 mm. in 14 to 20 (about 18) indicating a dip of 30° to 45°. In the Manitou Section 3 it seems to be cut out by a fault. Cf. Beds 79 and 80. But in Manitou 7 it is plainly Bed 80, the increase of grain being about 1 mm. in 12 feet.
Cf. also Franklin Jr. 666, Hole 3, 451-535.

It does not seem to be coarser grained than at the Central and Manitou or at any rate much so. If its thickness is similar (250 to 280 feet) it must be cut by the hole at an angle of near 45°.

61. Amygdaloid 649-652. (3)
Perhaps just a gush of the great ophite or part of the conglomerate below.

62. Amygdaloid conglomerate d 6. 652-657 (5)
Band of indurated sandstone dipping 33° at the top, then a quite distinct conglomerate.
Base below base of Wolverine sandstone
Cf. Central mine d 6. 59 and 60
Manitou b 81
Franklin Junior 67 at d 3. 535′ 4″.

63. Amygdaloid melaphyre (16)
d 6. 657-676
Greyish, decomposed in appearance

64. Ophite (121)?
Amygdaloid d 6. 676-699 (21)
Amygdaloid trap and breccia
Trap d 6. 699-814 + (100) ?
Disturbed with laumontite, and copper seams at 33.5°, at 737 fluccan?, near 737 big perpendicular laumontite seam, at 750 and lower, prehnite and copper, also seams at 59° to core.
At 704, 712, 730, 737, 782-802, 814 feet the mottles are
1 to 2, 2 to 3, 3, 4? 3 to 2 mm. invisible, respectively.
Manitou b. 82? Central b. 61 to 62 does not show it. Is there a fault repetition, 58, 59, and 60 being repeated in 62, 63, 64? It is possible.

It will be noticed that Mandan Hole 6 has no good correlation in either direction and therefore might have the steeper dip which is found in this last hole. The fact that a flatter dip was found to the north influenced me, perhaps, in assuming a somewhat too flat dip in this hole. Subsequent work on the Kearsarge lode shows that it dips about 46° and the section should be amended accordingly (Fig. 25), lengthening the section in the ratio 7/5 and narrowing the individual beds.

Mandan drill hole 4. The indication of dip in the upper parts of the hole average 33°¾. Such a dip would mean an overlap with Hole 6, and a reduction factor of 0.84. This is assumed, *but* the dip might be and probably is steeper.

1. Overburden 20

(64). Feldspathic ophite
Trap d 4. 28-49 (18)
Mottles 2-3 mm. at beginning, then finer.
Basal amygdaloid

Base below base of Wolverine, if this is 64 about (497)

(65). Sediment d 4. 49
Green epidotic dip (5:8) 32°
Cf. Mandan d 6. 652. This is the only correlation that can possibly be made for the hole in Bed 6 and is not impossible. The dip would then be 28.5°. But though not lithologically impossible it does not seem likely. If it does not appear in 6, however, there is no reason why the trap above should not be that at the base of Hole 6, the bottom of which is nearly reached. A dip of 33°¾ would be implied.

(66). Feldspathic ophite (33)
Amygdaloid d 4. 449-62 (11)
Green sedimentary contact dips 32°
Amygdaloidal trap d 4. 62-88 (13)
Coarse feldspathic, the amygdaloid bands dipping 33°⅔ to 35°⅔, at 91 and 93 feet, green amygdaloid inclusions or bands.
Trap d 4. 88-160 ?
At 98 there are 3-4 mm. mottles, at 117 calcite and laumontite seams at 45° and thence on. The trap becomes chloritic; reddish altered olivine is characteristic of the flow.

67. Feldspathic ophite, a glomeroporphyrite (40)
Amygdaloid d 4. 160-180 (17)
Looks like a basal amygdaloid, fine grained, glomeroporphyritic seams dip from 34° to 31, 28, 22°
Trap d 4. 180-208 (23)
Coarse, faintly mottled, with chloritic and altered olivine. There is a distinct tendency in these traps to feldspar phenocrysts with red porphyritic base. There is an amygdaloid streak, not a contact at 198-200.

68. Glomeroporphyrite, amygdaloidal (12)
Amygdaloid d 4. 208-223
Fine grained red porphyritic with small irregular amygdules and a well-marked basal contact dipping 28°.

69. Glomeroporphyrite. (54)
d 4. 223-277
At top poor with a glomeroporphyritic tendency, at 252 feldspathic, medium fine grained, growing finer, red and more markedly glomeroporphyritic.
Cf. Central mine Beds 97-115 and above.
Manitou d 7. d 6. 82-91. It is characteristic of this part of the column that the amygdaloids belong as much with the flow above as that below.

70. Amygdaloidal porphyrite (22)
d 4. 277-300 or 304
Coarse chloritic amygdaloid with fine grained porphyritic trap from 289 on.

71. Amygdaloidal porphyrite (43)
d 4. 304?-334? (25)
At 306 only a spot of amygdaloid, at 319-320 a green enclosure
At 328-334 glomeroporphyritic.

Here the hole crosses a much disturbed red belt or slide dipping 39° extending to 337 or 8. A calcite seam dipping about 28° is faulted by steeper seams. The motion seems both reversed and normal.

Trap d 4. 334-356 (18)
This may be some other bed.

72. Ophite (4 mm.)
Amygdaloid d 4. 356-364
Trap d 4. 364-460?

At	377,	381,	386,	391,	412,	418,	428,
	1 to 2,	2 to 3,	2 to 3,	3	6 (prism)	4,	3½-4,

454
1-2 mm.

At 418, 423 and 428 are doleritic spots with copper.
Cf. contact Bed 72, 607 feet below the Wolverine sandstone.

73.	Feldspathic ophite	(790)
	Amygdaloid d 4. 460-468 (7)	(49)
	From d 4. 462-65 epidote, then to 468 a dark and pink amygdaloid.	
	Trap d 4. 468-517 (42).	
	Coarse and faintly mottled	(839)
74.	Melaphyre	(23)
	Amygdaloid d 4. 517-522 (4)	
	Red and white	
	Trap d 4. 522-545 (19)	
	Fine grained	(862)
75.	Amygdaloidal melaphyre	(8)
	Amygdaloid d 4. 545-550 (4)	
	With chlorastrolite? thomsonite and calcite amygdules	
	Trap d 4. 550-556 (5)	(870)
76.	Amygdaloidal melaphyre	(11)
	Amygdaloid d 4. 556-565 (8)	
	Green with prehnite or thomsonite and copper	
	Trap d 4. 565-568 (3)	
76.	Amygdaloid d 4. 568-572 (3)	(20)
	Coarse, not a new flow and no contact, part of the trap, with open bubbles lined with crystals.	
	Trap d 4. 572-589 (14)	
	Amygdaloid base d 4. 589-592 (3)	(901)
77.	Amygdaloidal melaphyre (glomeroporphyritic)	(39)
	Amygdaloid d 4. 592-597 (4)	
	Trap d 4. 597-600 (3)	
	Glomeroporphyritic amygdaloid d 4. 600-603	(2)
	Amygdaloidal trap d 4. 603-607 (3)	
	Amygdaloid d 4. 607-608 (1)	
	Trap d 4. 608-610 (2)	
	Amygdaloidal trap d 4. 610-612 (2)	
	Trap d 4. 612-635 (20)	
	Amygdaloid d 4. 635-638 (2)	
	Trap d 4. 637-638 (1)	
	Fine grained	(940)
78.	Amygdaloidal melaphyre	(940)
	Amygdaloid d 4. 638-640 (2)	(13)
	Green with white crystals	
	Trap d 4. 640-642 (2)	
	Amygdaloid d 4. 642-644 (2)	
	Trap d 4. 644-649 (5)	
	Amygdaloid d 4. 649-652 (3)	
	Trap d 4. 652-653 (1)	

Contact appears to dip 55°. In general the apparent dip is near 45°. But in this part of the section not only is the dip steeper but the strike is not at right angles to the line of the section, which would tend to flatten the dip on that line.

79. Feldspathic ophite (4 mm.) (76)

Amygdaloid d 4. 653-654-666

Indications of 45° dip or more

Trap d 4. 666-743

With occasional amygdules of pink (copper bearing ?) prehnite as shown in the cuts back of R. C. Pryor's house, Houghton, near the Isle Royale lode.

At 675 feet a seam dipping 53° with calcite and copper.

At 686 a 2 to 5 mm. mottling, at 696 thomsonite, at 700 are seams at 71.5° to each other and at 28° and at right angles to each other. Then are specks of copper in a doleritic amygdaloid and at 707 a decomposed seam at 54°½ ?

At[1] 686,	708,	718 feet the mottles are	
2 to 5,	4,	3? mm. and then finer.	

(953)

80. Amygdaloidal melaphyre (14)

Amygdaloid d 4. 743-745 (2)

Poor, red

Amygdaloid trap d 4. 745-760 (13)

Joints dip 64° and there are amygdaloid streaks at 749, 752 and to 756. From 756-759 it is brecciated and chloritic.

(967)

81. Feldspathic ophite (33)

Amygdaloid d 4. 760-765 (4)

Red above, changing to cold yellow or greenish grey at the bottom as is so common.

Trap d 4. 765-799 (29)

Faintly mottled, growing finer from 785 on.

Cf. Central mine b 179. (1000)

82. Feldspathic ophite (27)

Amygdaloid d 4. 799-814 (13)

With laumontite, red and white above passing into green and white below. Trend of amygdaloid lines at about 45° to the core well marked.

Trap d 4. 814-831

Faintly mottled (14) (1027)

83. Sediment at d 4. 831

Only two or three inches dip 39° but note that more appears for some distance below at 835, 907 etc.

According to the probable dip it is 800 to 900 feet below b. 657 or 1167 to 1267 below the Wolverine.

Cf. Manitou 7 beds 92 to 96

Cf. Bed 81 (1042) below the Wolverine at the Central mine.

From this point on a reduction factor of .78 dip 39° is used.

84. Amygdaloid gush (3)

Amygdaloid d 4. 831-835 ?

Sedimentary contact beneath dips 45° (1031)

85. Amygdaloid d 4. 835-840 (4) (14)
Amygdaloid trap d 4. 840-853 (10)
Amygdaloidal spot d 4. 840-843
Sedimentary contact beneath dips 49°

(1045)

With these three sediment contacts cf. in the Manitou 7 section Beds 92 and 96.

86. Feldspathic ophite (10)
Amygdaloid d 4. 853-857 (3)
Trap d 4. 857-866 (7)
Faintly mottled with poor amygdaloid at base.

87. Feldspathic ophite (1055)
Amygdaloid ? d 4. 886-869 (2)
All sludge, chloritic, perhaps a seam
Trap d 4. 869-918 (38)

Feldspathic, faintly ophitic at 908 a clasolitic seam crossing at 45°, slightly amygdaloidal at 914 to 916, at 900 minute specks of copper in the trap.

88. Melaphyre (1096)
Amygdaloid d 4. 918-931 (10)

Flow lines numerous and well-marked and dip at 45°. The amygdules are hard and either thomsonite or prehnite.

Trap d 4. 931-1003 (56)

Not mottled, at least plainly. There are occasionally brecciated and amygdaloid spots (961 and 986) but on the whole it is massive. At 964-965 it is veined (66)

89. Melaphyre (1162)
Amygdaloid d 4. 1003-1009 · (5)

Green with pink bordered amygdules and a glomeroporphyritic tendency.

Trap d 4. 1019-1107 (1239)

Glomeroporphyritic with amygdaloid spots at 1015, 1020, 1023, 1050, 1062

Seamed at a 45° angle

90. Feldspathic melaphyre (77)
Amygdaloid d 4. 1107-1113 (5)
Black with red amygdules. Apparent dip 45° or so.
Trap d 4. 1113-1206 (73)
Massive feldspathic. At 1149 a fissure seam
Below Wolverine sandstone (1316)
We don't seem to have reached Central mine 96 or Manitou 7.

Mandan Holes 24 and 25 are in the shaft from the Medora to the Conglomerate.

Holes 10 (245 feet at 66°) and 13 (352 feet vertical) are about in the horizon of 12. Holes 11 (92 feet), 3 (1095 feet), 5 (405 feet) and 7 (732 feet) are about in the horizon of 12, looking at the Houghton conglomerate and Montreal lode. Hole 15 is about 4000 feet west of No. 10. Hole 22 (514 feet at 61° to S.) is about 1650 feet and No. 23 (551 feet at 62° ½ to S.) about 3130 feet east.

Exploring the Calumet and Osceola horizon, Hole 21 (460 feet at

61.5°) is 650 east and 250 south. Nos. 17 (167 feet at 61°), 18 (173 feet at 61°), 19 (12 feet at 60.5°) and 20 (144 feet at 61°) test the Kearsarge lode and are along the Montreal River 800, 1400, 2100, and 3350 feet east of the section respectively.

Mandan drill hole 17. Began in Kearsarge amygdaloid; an upper, not typical bed

1. Drift (28)
2. First Kearsarge amygdaloid d 17. 28-41
   Large occasional amygdules, altered, light green, like altered prehnite, with 10 mm. phenocrysts. Seams at 26° to core.
   Trap d 17. 39-62
   With dips nearly parallel to core from d 17. 56-60
3. Main Kearsarge amygdaloid and foot
   Amygdaloid d 17. 62-78
   Trap d 17. 78-105
   With large phenocrysts and copper at 89, 105 and 121
4. Wolverine sandstone about 105?
5. Ophite d 17. 105-146
   At 146 a calcite vein with lots of copper. Dip against core 29°. There are also gaping cracks at 32°.

Mandan drill hole 18. A specimen gave a good illustration of the Kearsarge foot and is reproduced in Plate VII.

1. Overburden
2. Grey, not mottled trap d 18. 34-44
3. Feldspathic melaphyre d 18. 44-84
   Amygdaloid d 18. 45-51
   Trap d 18. 51-84
   Chlorite blotches and 1 mm. feldspar
4. Kearsarge amygdaloid and foot porphyrite ophite
   Amygdaloid d 18. 84-90
   Trap d 18. 90-135-½ (See Pl. VII, for d 18. 90)
   Phenocrysts up to 25 mm. long; some red, some green; the red does not show twinning, mottled at about 106 feet, and from 134-135½ amygdaloidal and fine.
5. Wolverine sandstone, only an inch or two, green epidotized

[6.
   Amygdaloid d 18. 135-143
   Well-marked to 137 feet; spotty to 143 feet
   Trap d 18. 143-174
   With numerous brown specks of altered olivine

Mandan drill hole 19. Like 18. Dip 60°.

1. Overburden
2. Kearsarge amygdaloid and foot porphyrite ophite
   Amygdaloid d 19. 35-48
   From 35-43 is the amygdaloid proper with white amygdules of calcite,

PLATE VII.

Typical drill cores. Beginning from left to right, they are as follows:

20485 Manitou d. 3 at 122 feet represents amygdaloid conglomerate such as occurs at about the horizon of the Houghton conglomerate, Montreal lodes. Brown sedimentary matrix full of bubbles. Pebbles of amygdaloid with pink and white amygdules.

15295 (upper row) Isle Royale d. 7 at 295 feet. Cores from a "glomero-porphyrite," like the hanging of the Pewabic lode, near center of flow.

15384 (lower row) Is the same type near margin of flow.

17956 (upper row) Franklin Junior d. 3 at 345 feet. Kearsarge amygdaloid containing copper showing the difference between the round amygdules and the angular porphyritic feldspar in the center toward top of the core.

(lower row) Mandan d. 18, at 90 feet depth. Kearsarge amygdaloid foot—labradorite porphyrite, showing the pink and green phenocrysts of feldspar, characteristic of this flow, though the points where the two cores are taken are over twenty-five miles apart.

17999 (upper row) Mendota d. 3 4 N. at 460 feet. Doleritic texture.

20491 (lower row) Mendota d. 40 at 55½ feet. Smooth bit of fine grained felsite (should be somewhat redder in tone than the core immediately to the left, and should give impression of smoother or finer grain).

prehnite, quartz crystals and copper after the prehnite and in quartz crystals. It then passes into an amygdaloid trap with chloritic amygdules and copper. The phenocrysts of labradorite are 15 mm. long and speckled green.

Trap d 19. 48-89

With large phenocrysts and at the same time with augite mottles, 2 mm. at 77, finer at 86

A pink fissure at 26° to the core; probably nearly vertical cross-cut at 67.

3. Wolverine sandstone d 19. 89-90

A red basic, fine grained conglomerate or shale, about 11° from being perpendicular to core, indicating a 41° dip.

4. Ophite

Amygdaloid d 19. 90-96

Trap d 19. 96-114

Pink and blotched to 105

No. 26 was vertically north of No. 19 800 feet, while a pit on the Kearsarge lode was 100 feet south and found the Kearsarge amygdaloid so deep that a dip of some 46° was indicated.

In almost direct line with the Mandan section is the Mendota section beneath and the work of F. E. Wright (Annual report for 1908). Just how much of the Mendota section is cut out by the slide in Hole 4 is uncertain. Hole 4 should cover about half a mile south of the Montreal River. This would leave about half a mile uncovered to the Bohemia conglomerate, in the north part of Section 29,—the series of conglomerates and felsites which Hubbard has covered. (Vol. VI, Pt. II and above § 2). The section below, quite possibly beginning in the very bed in which Hubbard left off in the Montreal section, is given by the Mendota section (Fig. 26) which brings us down to a conglomerate under a heavy trap in which an acid rock is intrusive (Ss. 20487 to 20500)—a felsite porphyrite. In the Mendota section, 1400 feet of thickness = about 1600 feet horizontally. The Lac La Belle conglomerate, the first marked conglomerate beneath a heavy series of ophites, with a very heavy one (the Mabb ophite?) just above. This suggests, comparing the section at the Isle Royale (Fig. 44), that we have here the section above Conglomerate 3 with the beds thickened.

Mendota section. W. J. Penhallegon, Superintendent. Part of the Calumet and Hecla explorations. Fig. 26. Runs practically due north and the exact strike probably varies from 11 to 15° from the line of section.

The tangent of the dip should thus be increased by (cos 11° to 15° or possibly more) 2 or 3 % and all horizontal distances in the same proportion (97 to 98 % of these along the section) in order to get a section at right angles to the strike.

Thicknesses will be reduced in the ratio not far from cos x where tan x = tan 11° sin 40 therefore

x = about 8° and cos x = .99

The error is therefore probably insignificant. That the holes are nearly at right angles to the beds is also shown by the rapid increase in grain of the ophites.

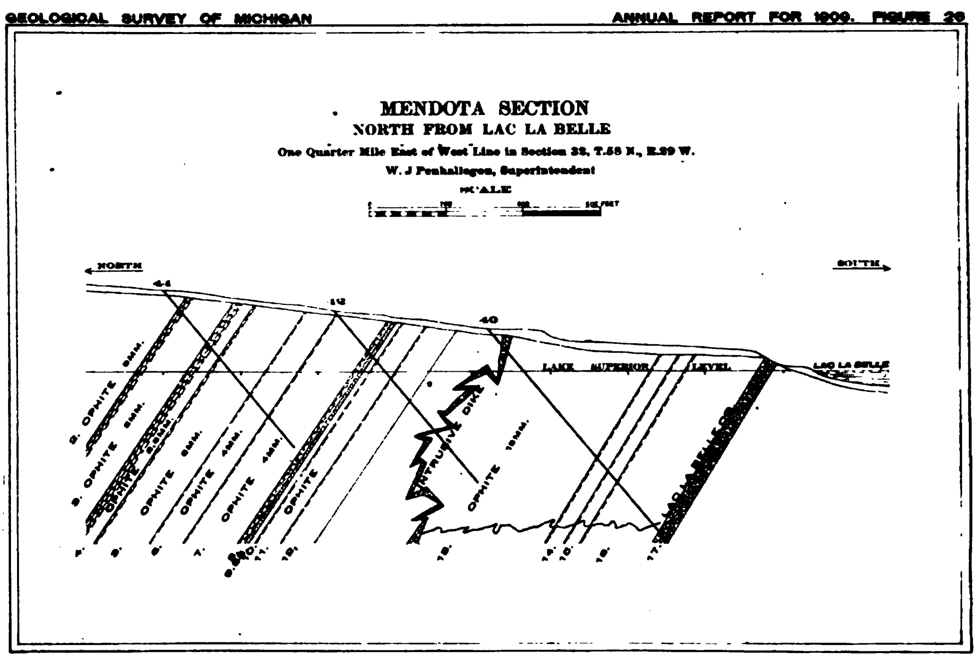

Fig. 26 Mendota cross-section north from Lac La Belle, ¼ mile east of west line in Section 32, T. 58 N., R. 29 W.

Mendota drill hole 44. 1680 feet north of Lac la Belle, ¾ mile west of east line of Section 32, T. 58 N., R. 29 W., 210 feet above Lake Superior. Dip of hole 50°, of strata probably 43°. The deviation of these strata from a line at right angles to the hole should not be over 10°. Thus no appreciable error is made in the thickness. The general character of the heavy ophite beds is much like that of the Atlantic crosscut on Section 18, but there are epidote tops instead of amygdaloid conglomerates. The heavy bed 13 may represent the ophite and the Lac la Belle conglomerates, Conglomerate 3, and the Baltic conglomerate.

1. Overburden 16 feet
2. Ophite (6 mm.+) (80-)
   Trap d 44. 16-59
   Grows finer; 20, 26, 40 to 43, 50 to 51 feet the mottles are
   4, 6, 2 to 3, 1 to 2 mm.
3. Ophite (5 mm.) (112)
   Amygdaloid d 44. 59-77
   At 59-60 and 67-68 light colored, yellow, grey and white, coarse epidotic generally

Trap d 44. 77 to 172

Seamed at 77 feet and at 134, at 30° at 84; faintly mottled from 166-172, on

at 86, 123 to 127, 153 feet the mottles are
3, 5, 2 to 3

4. Ophite 2-½ mm. (51)

Amygdaloid d 44. 172-194

Epidotic and chloritic to 179 or 188, continues with calcite and laumontite seams to base.

Trap d 44. 194-223

At 194, 204 to 205 feet the mottles are
1, 2 to 3 mm., then finer.

5. Ophite (5 mm.) (124?)

Amygdaloid d 44. 223-228

From 223-225, apparently epidote and there are epidote streaks at 230 and 230 ½. The epidotic chloritic amygdaloid seems, however, to go only to 228.

Trap d 44. 228-347

At 249 to 258, 287, 293 to 300, 337, 344, 354 feet mottles are
3 to 4, 4, 5 3, 2-3, 1-2 mm.

The formation is evidently disturbed, as the grain shows.

Between 260 and 306 feet are seams, some presumably nearly vertical at 30° and at an angle of 71.5° to the core. We may interpret them that the north side of the core is moved east.

At 340, 344 and 358 are epidote bands, at 344-347 is epidote and amygdaloid with fissures

6. Ophite (4 mm.) 78

Amygdaloid d 44. 347-350

Trap d 44. 350-421

At 392 the mottles are 4 mm., then it is finer to 421

7. Ophite (4 mm?) (108?)

Amygdaloid d 44. 421-444

Alternating epidote and epidotic grey amygdaloid with laumontite seams, yellow epidotic 423-428

Trap d 44. 444-529?

Coarsest above 511. d 44. 511 matches well enough in grain d 42. 133. The mottling is banded in alternations of fine and coarse from 1 to 4 mm., at 459, at 467 it is 3 mm.

At the end from 511 to 529 it is brecciated and very epidotic.

On the whole the hole is unpromising. There is an unusually large amount of bright, yellow green epidote.

Mendota drill hole 42. 1236 feet from Lac la Belle, 156 above it, Lake Superior. Dip of hole 50°. It should lap the bottom of Hole 44 which it may very well do. Correlating d 42. 133 and d 44. 511 means a dip of 50°. A point 70 feet down in 44 is on a level with 42 and 399 feet from it.

Overburden 14-feet

? (7) Ophite (4 to 6 mm.) (117?)

Trap d 42. 14-133
Epidotic at 20 to 21 and 50, seamed at 75 to 87, at
56, 75, 87 feet the mottles are
2, 3 or 4 to 6 mm. and at 87 it is coarsest and grows finer below. Nearly the whole flow must be represented.

No higher position or less dip can be allowed as the epidotized sandstone and amygdaloid conglomerates d 42. 140-155 is not represented in d 44.

8. Amygdaloid
Amygdaloid d 42. 133-146
Red and white

9. Sediment
Epidotized sandstone ? d 42. 146-155
Some amygdaloid conglomerate also

10. Melaphyre.
Trap d 42. 155-170
The relations of 8, 9 and 10 are not quite clear, one would suspect misplacement of core.

11. Amygdaloid d 42. 170-172
Trap d 42. 172-224
There are slickensided seams which make an angle of less than 12° with the hole. At 192-210 are faint 1 mm. mottles.

12. Amygdaloid d 42. 224-227½, and 230-235
Epidotic brecciated
There are also epidotic streaks at 240-242, 252½-253½, 254-260, 259-270, 280-284
Trap d 42. 235-302
This all appears fine grained and the change in grain at 302 is sudden as though there were a displacement there.

13. Ophite (12 mm.)
Trap (with intrusions) d 42. 302-577
At 302, 333, 382, 391 feet the mottles are
3, 7, 7 to 9, 9-10 mm.
At 400-405 is a felsitic intrusion with sulphides.
At 422, 440, 450 feet the mottles are
8 to 11, 9 to 10, 4 to 5 mm.
At 445 it is seamed parallel to the hole and the grain is coarser again; at 482 to 499 the mottles are 10 mm.
At 510 and 520 the mottles are
10 and 12 mm. respectively and as coarse at 577.
At 499-502 is a coarse feldspathic, that is, doleritic streak and again at 530 and 533.
Where it is seamed the pattern is sometimes plainer, sometimes fainter. At 529 in a seam practically parallel to the hole is chalcopyrite. The bed evidently occurs at the top of 40. While in a way d 42. 400-405 corresponds to d 40. 55 to 74½, one can not base any correlation on that as an intrusion, neither can one correlate by grain as there has been so much faulting.

Mendota drill hole 40. 340 feet from Lac la Belle, and 100 feet above it, the strong terrace there being about 110 feet above the lake.

A point 73 feet down in No. 42 and only (1236-840 difference in altitude (56) x

cot 50°) 349 feet from the top of No. 1 is on a level with it. There must therefore be a great overlap of 40 and 42.

Overburden 19 feet

13. Ophite (15 + mm.) about (400)

Trap d 40. 9-435 (with intrusive felsite)

At 16 and 49 the mottles are 10 mm.

At 53 to 74½ is a compact felsite porphyrite, Ss. 20486-20500

At 81,	105-118,	172,	283,	330,	380	feet mottles are
9,	10-15,	15 +,	13 +,	10-12,	(7 to 8) x 4 mm. prisms	

At 403,	416,	434 feet the mottles are	
4,	2,	½ mm.	

The rate of increase of grain shows that this ophite is cut nearly at right angles. Hole 42 does not show any of the bottom finer grain and therefore can not correspond to any thing below say d 40. 330, nor can d 40 16 correspond to anything above d 42. 391. The dips, faulting apart, must then be between 23.5° and 57° (averaging 40°). Penhallegon told me that the dip from the outcrop of the conglomerates cut at d 40. 685 to that point was 62°.

At 106-110 it is chloritic, at d 40. 148 are crystals of a zeolite. Cf. this with the big ophites at Sand Bay, Mamainse.

This heavy ophite is of some especial interest. Its coarsest grain leads to knobs half an inch across, easily recognized in the field, and as a matter of fact both F. E. Wright, in his Mt. Bohemia work,[7] and Hubbard[8] mention it. The exposure which Irving refers to as in the south part of Section 4, T. 56, R. 31,[9] may refer to an exposure 1980 paces north and 550 paces west, i. e., close to Section 4, T. 57, R. 31, for the location given is surely a misprint.

Such a heavy flow should be fairly persistent and one is tempted to correlate it with the Mabb ophite, the heaviest flow at about this horizon in the Isle Royale section.

The intrusion into the ophite was of especial interest, and it seemed especially worth while to see whether it were connected with felsites like these of the Bare Hills or the red rock associated with the Mt. Bohemia Gabbro, described by F. E. Wright.

It is rather notable that in most cases intrusive red rocks seem to me to be associated with *large* masses of ophite.[10]

The specimens are 20486 to 20500. Cf. 16919, 525 N. 615 W. Section 29, T. 58 N., R. 29 W.

The rock proves to be like Hubbard's felsite porphyrite (Beds E and G of Volume VI) not like the gabbro aplites, having a ground mass of elongate sub-parallel orthoclase and oligoclase (about 0.2 mm. long and .05 wide) with magnetite (.025 mm.) chlorite, epidote, calcite and enclosures in which the feldspar is less parallel. One phenocryst has extinction angles 23°-10°. Comparing center and margin the main change is that at the center the crystals are broader.

Sp. 20486 (Mendota d 40. 74½) is a specimen of the ophite immediately adjacent to the red intrusion. The original mottles are pretty thoroughly altered to chlorite and calcite and appear lighter. Iron oxide appears to have been crowded out from them and the chlorite is less abundant. The mottles are from 5 to 10 mm. across averaging about 8 and about as coarse as at 16, 49 and 81 feet. It is

[7] Report for 1908.

[8] Vol. VI, Pt. II, Pl. IV, Fig. 8, pp. 72-73.

[9] Monograph V, Copper-bearing Rocks of Lake Superior, p. 176.

[10] For instance, at Mamainse both near Roussain's and near Sand Bay, Mt. Bohemia, Porcupine Mountains and south at Berglund, Bad River? Duluth?

noteworthy that this ophite does not have any uralite such as occurs in the ophite next to the gabbro aplite intrusions but Wright says that a direct change to chlorite, such as we have here, also occurs there. The feldspar extinctions lead to an andesite composition much such as Wright found for the red rock.

Sp. 20487 is also at 74½ feet and from the "red rock" immediately adjacent to the ophite. It is decidedly finer than 20494 but this is due not so much to the length of the feldspar as to their thickness. In extreme length there is no material difference though in average length 20494, near the center of the intrusion, is probably somewhat coarser.

Sp. 204891 (72 feet) is 2½ feet from the contact and is distinctly coarser and more crystalline than 20487 which is from the extreme edge. The oligoclase is from 0.1 to 0.3 mm. long by .02 to .03 across, occasionally .04 to .05 across. It will be noticed that the variation in coarseness of the feldspar is in thickness rather than in length. The needle-like character of the feldspar suggests rapid under-cooling. The iron oxides are very different from those in Sp. 24087, for they are in compact coarser dots, 0.01 to 0.02 mm. across.

Sp. 24093 at 67 feet, that is 7½ feet from the bottom, shows an enclosure of the fine grained margin as a fragment in the coarser grained middle type. There seem to be also long amygdules of calcite and chlorite. The oligoclase is mainly .1 to .2 mm. by 0.02 to 0.06. In the enclosed fragment they are about one third the size. Iron oxides run from 0.02 to 0.3. Chlorite is abundant.

Sp. 20494 at 64 feet is close to the middle. There are amygdules 1 to 8 mm. in length pulled out so that the longest direction is parallel to the feldspar flow lines. They have a chlorite margin and a calcite center. It shows the twinning and a sheaf-like parallel arrangement of the feldspar common in the trachytes. This is, however, perhaps not wholly flow arrangement but one of crystallization or of pressure and affected by the flow of heat to the margin. Yet since the length of the feldspar individuals was obtained before their breadth, their arrangement might be affected by the flow. This fine grained belt of microlitic, often forked, feldspar is largely not over .06 mm. x 0.003 mm. They rarely show twinning and the extinctions are between 0° and 4°. Occasionally there are larger rhyocrystals up to 0.25 mm. long x 0.02 to 0.03 mm. wide. There are numerous round forms about 0.06 mm. across, which may possibly represent altered phenocrysts, but look like minute bubble pores filled with secondary chlorite and quartz. The iron oxides are in tree-like forms 0.01 mm. x 0.05 mm. There are occasionally larger flecks of iron oxide up to 0.40 mm. Calcite occurs in patches. There is some epidote diffused in the larger feldspar. Probably much of the rock was glass which is now changed to a mosaic of quartz and chlorite (with the latter dominant) and a little epidote and iron oxides. The iron oxides are such as occur in glass. The feldspar seems to be $Ab^3 An^2$.

Of Sp. 20496 (Mendota d 40. 61) two sections were made to check. The oligoclase is very fine grained, mainly .1 to .15 x .01 to .02 mm. The iron oxides are .01 to .02 mm. Chlorite occurs and calcite and quartz amygdules are common. Epidote occurs and also fragments of the finer grained margin.

Ss. 20493, 20494 and 20496 are similar in grain and 20500 is nearly so. 20489 is fine but certainly not half so fine. 20487 shows distinctly a finer, glassy marginal facies but with the feldspar already developed in length. Our inference is that the grain of the center is not over .024 of what it would be were the rate at the margin continued through the whole thickness affected, but it is more than .02. The ratio, therefore, of the initial temperature or the temperature of consolidation would be between .9 and .8. This relatively high value, as well as the glassy margin and the amygdules, suggests that the consolidation was at no great depth so that

the gases were allowed to escape and the temperature of the surrounding rock was very considerably below the temperature of crystallization. I am inclined, therefore, to believe that this rock, as already suggested, is referable to the period of eruptive activity which led to the overflows at the top of the Bohemia Range group. It is, however, possible to believe that the greater distance from the Mt. Bohemia gabbro would lead to a colder country rock and a greater chance for gases to escape and so produce a rock of this type. I do not think it, however.

14. Melaphyre (44)
    Amygdaloid d 40. 435-439 (4)
    Epidotic
    Trap d 40. 439-479 (40)
    Fine grained with epidote streaks at 439 and 451
15. Melaphyre (36)
    Amygdaloid at d 40. 479½-480½, again at 508-510
    Trap d 40. 480 ½-515 near Baltic lode horizon (170)
16. Amygdaloid d 40. 515-517-521
    Epidotic d 40. 517-521
    Trap d 40. 521-685
    Faintly ophitic; with calcite and laumontite, the latter very abundant at 582.
    At 665 is an intrusion of red rock, gabbro aplite?
17. Conglomerate d 40. 685-720, (No. 3?)
    At 691 clay, at 696 seamed (9: 5 to 7) at 28° to 35° to hole, perhaps nearly vertical seams dip from outcrop 62° according to Penhallegon,

§ 5. MANITOU-FRONTENAC (FIGS. 27, 28 AND 29).

Passing on west from the Mandan section we cross a couple of topographically well-marked fissures on the old Resolute property, Section 18, T. 58 N., R. 29 W., which I think run clear across the point and have something to do with the location of Agate Harbor.

We come next to the old Delaware-Pennsylvania-Conglomerate Pawnee properties, (Fig. 27) which have had a long history of explorations, and have lately been taken under the wing of the Calumet and Hecla. Most of the mining exploration has been on veins close under the Greenstone. There were, however, a number of pits opened on a lode close to the Montreal River, hence called the Montreal amygdaloid, which close to a fissure was fairly well charged with copper. It did not, however, prove to be extensive. Then a few pits as shown in Figure 27 were opened on Section 24 near the horizon of the Kearsarge amygdaloid, one of which had a good showing of copper.

Beginning at the east we have the Section Manitou 7, which extends farthest south of any of the sections we have, and should, indeed, have gone to the Bohemia conglomerate, had it continued without deviation or faulting from an outcrop only a mile east. Judging from the beds of the Arcadian section in comparison with

these, I think it should have reached it soon anyway. It will be noticed that I believe there is a gap in the record caused by a fault crossing 7 Hole 4 S. This is not so far from being continuous with the strike fault found at Mandan. Of course, the same effect on the drill core record might be due to faults with many variations of strike.

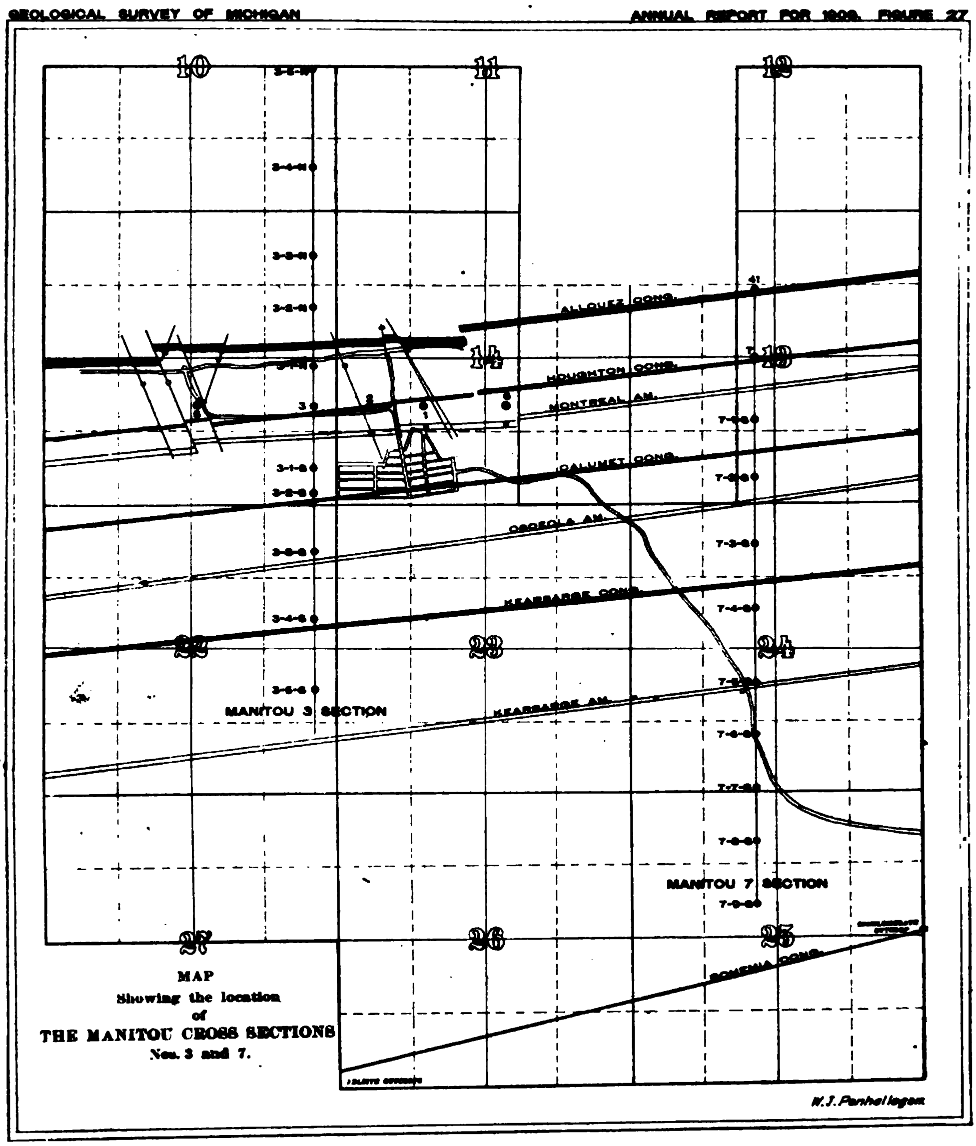

Fig. 27. Map showing location of Manitou-Frontenac section near Old Delaware and Pennsylvania properties.

Manitou Mining Co. Sec. 7. (See Fig. 28 in envelope). This section across the Manitou-Frontenac property was not looked over by Lane entirely, as W. J. Penhallegon had made a careful record.

The following is a record of the section, with the holes Lane examined underscored. The complete section from Penhallegon's notes is given in Fig. 28.

Hole No. 7	Feet from 0	Elevation	Angle
.0	300	520	60°
1	11 + 50	505	60.5°
2	22 + 02	515	65°
3	34 +	560	65°
4	46 +	575	65°
5	59 + 38	580	65°
6	68 + 60	565	60°
7	77 + 18	578	59°
Line S. 24 to 25	79 + 15		
8	86 + 84	570	55°
9	98 + 00	570	57°

In this part from the Calumet conglomerate down to the Kearsarge conglomerate the correlation of sections Manitou 7 and Manitou 3 is easy and can be made *almost bed for bed* the whole way, though the sections are a mile and a half apart.

Manitou 41 only 300 feet off the line may be used to complete the correlation and gives the position of the Medora and "Manitou" lodes.

Correlation with Manitou 3.	*Manitou drill hole 41.* Nearly in line with No. 7 section at an angle of 65°
(19)	1. The greenstone.
	Trap d 41. 22 - 35
	The mottles are 2 mm. (with chlorite slips) at 22.
(20)	2. Allouez conglomerate d 41. 35-57
	Base has a weathered (?) contact.
(21)	3. Melaphyre
	Amygdaloidal trap d 41. 57-60
	Trap d 41. 60 - 71.
(22)	4. Melaphyre.
	Amygdaloid d 41. 71 - 75
	Coarse
	Trap d 41. 75 - 92.
(23)	5. Amygdaloidal melaphyre
	Amygdaloidal trap d 41. 92 - 99
	Contacts at d 41. 92, 92½ and 96
	Trap d 41. 99 - 120.
(24?)	6. Amygdaloid d 41. 120 - 124
or	Amygdaloidal trap d 41. 124 - 136, with copper
(25?)	Trap d 41. 136 - 162
	This is presumably just above the Medora lode, below base of Allouez conglomerate. (105)
(26)	7. Feldspathic ophite. Medora lode
	Amygdaloid d 41. 162 - 169
	Amygdaloid trap d 41. 169 - 188

With pink prehnitic copper-bearing spots.
Trap d 41. 188 - 217,
Faint coarse mottles.

(27) 8. Feldspathic ophite. Manitou lode
Amygdaloid d 41. 217 - 225
Trap with copper d 41. 225 - 252
Coarse, massive chloritic, faintly mottled.

The intermediate holes between drill hole 41 and drill hole 7.4.S., to wit, 7.1.S., 7.2.S., and 7.3.S., were not examined by me and their records ran very closely parallel to Manitou 3. Their position and the belts found in them as determined by Mr. Penhallegon are given in Figure 28.

Manitou drill hole 7. 4.S at 4600 of section. Elevation 574. Dip 65°. This is an easily correlated hole as it shows the Wolverine sandstone at 641 feet. It is practically at right angles to the formation.

Corresponding belts in Manitou 3, Fig. 28.			
	1.	Overburden	(18)
	2.	Feldspathic ophite	(17)
	3.	Amygdaloid 7 d 4 S. 35-40 (5) Red glomeroporphyritic, with sediment, epidotic Trap 7 d 4 S. 40-47 (7) Amygdaloidal, fine grained Cf. Manitou 3 beds 59 to 61	(12)
	4.	7 d 4 S. 47-48	(1-)
(63)	5.	Amygdaloid 7 d 4 S. 48-55 (7) Trappy, probably 3 to 5 are all one bed of amygdaloid with clasolitic sediment. Trap 7 d 4 S. 55-123 (68) Grows darker toward base, with amygdaloidal spots at 83, and a doleritic streak with a speck of copper at 90.	(75)
(65)	6.	Ophite Amygdaloid 7 d 4 S. 123-125 Trap 7 d 4 S. 125-182 (57) At 130, 150, 174, 177, 182 feet mottles are 1, 3, 2, 1½ mm. contact	(59)
66)	7.	Feldspathic ophite Amygdaloid 7 d 4 S. 182-184 Red and white with prehnite and a little copper Trap 7 d 4 S. 184-288 Down to 190 glomeroporphyritic, and from 199 - 252 all coarse feldspathic, coarsest (about 10 mm.) at about 231. At 250 and 270 3 mm. mottles; at 270 a chlorite seam at an angle of 16°½. Beds 6 and 7 are the nearest match to the large ophite bed in M. Frontenac 3.4.S. 439-664.	(106)
(70)	8.	Melaphyre Amygdaloid 7 d 4 S. 288-293 (5) Trap 7 d 4 S. 293-296 ? (5) Red porphyritic ? contact at 296 ? Trap 7 d 4 S. 296-336 (40) Coarser	(50)

(71) 9. Sandstone 7 d 4 S. 336-342 (6)
Cold, epidotic, grey-green color; bedding at right angles to the hole.

(72) 10. Melaphyre (11)
Amygdaloid 7 d 4 S. 342 - 347 (5)
Trap 7 d 4 S. 347 - 353 (6)
While 71 and 77 really match in the two sections, the intermediate beds do not. The fact that there are the same number of beds is purely accidental it would seem, and they are given the same numbers for convenience.

73? 11. Amygdaloidal melaphyre (54)
Amygdaloid 7 d 4 S. 353 - 375 (22)
Yellow, coarse
Trap 7 d 4 S. 375 - 407 (32)

74? 12. Feldspathic melaphyre (37)
Amygdaloid 7 d 4 S. 407 - 410 (3)
Amygdaloid trap 7 d 4 S. 410 - 444 (34)
Coarser to 429; then finer and seamed.

75? 13. Feldspathic melaphyre (69)
Amygdaloid 7 d 4 S. 444 - 446 (2)
Trap 7 d 4 S. 446 - 513 (67)
Coarser feldspathic amygdaloidal,
(possibly more than one flow)

76? 14. Feldspathic ophite (96)
Amygdaloid 7 d 4 S. 513 - 517 (4)
Red and white, passing into trap with chlorite amygdules
Trap 7 d 4 S. 517 - 609 (92)
Doleritic at 550 coarse and faintly ophitic from 553 down.

(77) 15. Kearsarge amygdaloid and foot (32)
Amygdaloid 7 d 4 S. 609 - 613 (4)
Well marked contact, black and white amygdaloid.
Trap 7 d 4 S. 613 - 641 (28)
Few porphyritic labradorite crystals, long, not very well marked.

(78) 16. Sediment. Wolverine sandstone ? 7 d 4 S. 641 - 649 (6)
Grey-green, epidotic, with fragments of red amygdaloid and at base a regular amygdaloid conglomerate with dark amygdaloid and red matrix.

(79) 17. Ophite variously mottled (50)
Amygdaloid 7 d 4 S. 649 - 654½
Trap 7 d 4 S. 654½ - 699?
The mottling is well marked but very various in size as in some of the Torch Lake beds, especially from 675 to 680. Does this mean irregular initial temperature or composition? The same range appears in 7 d 5 S. from 23 ½ feet down.

(80) 18. Ophite (part of bed above) (100 +)
Amygdaloid 7 d 4 S. 699-728
Trap 7 d 4 S. 728 - 743-797 +
Ophitic variously mottled up to 3 x 1 mm., amygdaloid spot at 743; grows finer at the end, fine grained and full of chloritic seams, many at 45° to core, also at other angles.

Manitou drill hole 7. 5. S.

1. Overburden

(77) 2. Kearsarge amygdaloid foot trap

Trap 7 d 5 S. 16 - 22 (6+)

The first three feet have large 16 x 4 mm. characteristic feldspar crystals of the Kearsarge foot trap.

The rest of the way the core was in small fragments and the rock evidently disturbed by the slide.

(78) 3. Slide cutting out Wolverine sandstone (1)

Clay fluccan 7 d 5 S. 22 - 23

Central mine b 56.

(79) 4. Ophite (31)

Amygdaloid 7 d 5 S. 23½ to 25½ (1½)

Trap 7 d 5 S. 25 - 54 (29)

At 25, 32, 47 feet the mottles are 1, 1 - 2, 2 - 3 and finer. There is considerable variation in size of mottling. Central mine b 57

(80) 5. Ophite (12 mm.) (279)

Amygdaloid 7 d 5 S. 54 - 58½ (4½)

Cf. Mandan d 6. 239

Trap 7 d 5 S. 58½ - 333 (274½)

At	66½,	75,	82,	the mottles are
	3 to varied,	3 to 1 irregular,	4,	

106,	114,	163,	176,	220,	229,	277,
5,	7 to 10,	10,	12,	8,	8,	4,
285,	304,	312,	320			
3,	2,	1½,	1			

Central mine b (58)

(81) 6. Contact of sediment at 333

Cf. Mandan d 6. 649

(82) 7. Doleritic ophite (218)

Amygdaloid 7 d 5 S. 333 - 340 (7)

Coarse feldspathic

Trap 7 d 5 S. 340 - 551 (211)

Coarse ophitic

At 381,	382,	419,	439 feet the mottles are
3–4,	3 doleritic,	5 - 6,	8 mm. across
439 - 487,	521		
10 +	3		

It is coarser and doleritic at 411, and there are chlorite seams from 487 to 551.

(83) 8. Doleritic ophite

Amygdaloid 7 d 5 S. 551 - 555½

Trap 7 d 5 S. 555½ - 606

Marked feldspathic, doleritic.

Manitou drill hole 7. 6. S. at 68 + 60 of section. Elevation 565. dip 60° nearly at right angles to dip. No correlation for thickness necessary. It should overlap 5 considerably and either there is a steep dip or a faulting, for we do not find Bed (80).

If we assume the Central mine or some other section not to be badly

faulted we can estimate the amount of throw. If Bed (80) = Central mine bed (58) and the sediment 7 d 6 S. at 56 to 60 feet = Central b (60) the section is continuous.

1. Overburden (17)

(82) 2. Glomeroporphyritic (4 mm.) ophite
Trap 7 d 6 S. 23 - 56 (33) (+ 30?)
Finer from 28½

3. Sediment with copper
Red, fissured 7 d 6 S. 56 - 60 (4)
Dip 10½ to 12° from right angles to core
Central mine b (60)

(83) 4. Melaphyre (70)
Amygdaloid with sediment 7 d 6 S. 60 - 76
Green sediment 7 d 6 S. 65 - 68, and 75 - 76, chloriti amygdules and breccia.
Trap 7 d 6 S. 76 - 128
Coarser to 112, then finer to 128

(84) 5. Melaphyre (57)
Amygdaloid ? 7 d 6 S. 128 - 145 (17)
128 to 130 epidote and datolite, at 145 amygdule with a speck of copper
Trap 7 d 6 S. 145 - 185 ? (40)
It is characteristic of these beds as of corresponding beds in the Central mine that the amygdaloids and contacts are ill-defined.

(85) 6. Sediment at 185

(86) 7. Melaphyre (52)
Amygdaloid 7 d 6 S. 185 - 191 (6)
Trap 7 d 6 S. 191 - 237 (46)
Feldspathic to 200; at 202 green porphyritic; grows finer.

(87) 8. Melaphyre (20)
Amygdaloid 7 d 6 S. 237 - 239 (2)
Well-marked
Trap 7 d 6 S. 239 - 257 (18)

(88) 9. Melaphyre (49)
Amygdaloid 7 d 6 S. 257 - 267 (10)
Trap 7 d 6 S. 267 - 304 (37)
Green altered at 275, coarse feldspathic blotched with green at top, darker and finer toward the bottom.

(89) 10. Amygdaloid 7 d 6 S. 304 - 306
Amygdaloid trap 7 d 6 S. 306 - 311
Trap ? 7 d 6 S. 311 - 338

(90) 11. Feldspathic melaphyre (44)
Amygdaloid ? 7 d 6 S. 338 - 347 (9)
Red porphyritic base of bed above ?
Amygdaloidal trap 7 d 6 S. 347 - 353 (6)
Coarse feldspathic
Trap 7 d 6 S. 353 - 382 (29)
Massive feldspathic

(91) 12. Feldspathic melaphyre (13)
Amygdaloid 7 d 6 S. 382 - 385½ ? 13½
Mixed

Trap ? 7 d 6 S. - 395 10
Red, porphyritic from 392 - 94

(92) 13. Sediment 7 d 6 S. 395 - 399 (4)
Mixed and epidotic, perhaps a clasolite.

(93) 14. Ophite (3 mm.) (54)
Trap 7 d 6 S. 399 - 453
Mottling at 416 3 mm.; at 411 a laumontite seam, and at other places, laumontite seams parallel to the bedding; at 416 3 mm.; at 440 3 to 4 mm. mottles.

(94) 15. Ophite (4 mm.)
Amygdaloid 7 d 6 S. 453 - 457
Trap 7 d 6 S. 457 - 468
Trap fine grained but no marked contact 468 - 471
Trap 7 d 6. S. 471 - 536
Coarser at 484, 503, 516 feet mottles are
2, 4, 3 to 4 mm. across and pretty well marked.

(95) 16. Amygdaloidal melaphyre (23)
Amygdaloid 7 d 6 S. 536 - 545 (9)
Coarse
Amygdaloidal trap 7 d 6 S. 545 - 559 (14)
Trappy, then from 554 - 556 green and white amygdaloid, then coarse chloritic.

(96) 17. Sedimentary contact at 559
Cf. Central b (76)

(97) 18. Amygdaloid 7 d 6 S. 559 - 567
Chloritic and fine grained.

In this hole the group of beds characterized by a poor chloritic amygdaloid and red porphyritic foot is marked. 7 d 6 S. and 7 d 7 S. were intended to overlap but they do not appear to, unless 7 d 6 S. 471 = 7 d 7 S. 54 and that is not a very good match.

Manitou drill hole 7. 7. S at 77 + 18 of section. Elevation 578 A. L. S. Dip 59°. The line between Sections 24 and 25 is at 79 + 15 of section.

1. Overburden (19)

(96) 2. Ophite (4 mm.) (35 +)
Trap 7 d 7 S. 19 - 54

(97) 3. (63)
Amygdaloid 7 d 7 S. 54 - 61 (7)
Trap 7 d 7 S. 61 - 117 (56)
There is a green and white amygdaloid inclusion at 83.
The basal contact at 66° with core is well marked.

(98) 4. (18)
Amygdaloid 7 d 7 S. 117 - 127 (10)
Red and white marked
Trap 7 d 7 S. 127 - 135 (8)

(99) 5. (23)
Amygdaloid 7 d 7 S. 135 - 139 (4)
Trap 7 d 7 S. 139 - 158 (19)
With specks of amygdaloid

(100) 6. Amygdaloidal melaphyre
Amygdaloid 7 d 7 S. 158 - 179 (21)
With streaks of trap, fissured (pink) at 174

(101) 7. Ophite (4 mm.) (101)
Amygdaloid 7 d 7 S. 179 - 190 (11)
Trap 7 d 7 S. 190 - 280 (90), fine grained to 195, then a hard fine grained amygdaloid inclusion perhaps 195 - 197, then coarser.

At	223,	247,	258 feet the mottles are
	3,	4,	3 mm. across

At 276 is a datolite seam, possible contact, cf. Central b 79.

(102) 8. Melaphyre 7 d 7 S. (19)
Amygdaloid 7 d 7 S. 280 - 289½ (9½)
Coarse, poor
Trap 7 d 7 S. 289½ - 299 (10)

(103) 9. Doleritic ophite (6 mm.) (82)
Amygdaloid 7 d 7 S. 299 - 310 (11)
Poor
Trap 7 d 7 S. 310 - 381 (71)
Ophitic, at 346 6 mm.; at 321 and 326 doleritic.

(104) 10. Melaphyre (111)
Amygdaloid 7 d 7 S. 381 - 395 (14)
Trap 7 d 7 S. 395 - 492 (97)
Much seamed at 399, some green sediment and epidotic clasolites, spots of amygdaloid at 429, 431, and 433 and 460; fissures parallel to the hole at 445, at 487 and 495, and a breccia at 483, which may be the main slip.

(105) 11. Melaphyre (58)
Amygdaloid 7 d 7 S. 492 - 515 (23)
Brecciated, prehnitic, with epidote and quartz
Trap 7 d 7 S. 515 - 550 (35)

(106) 12. Feldspathic (ophite ?) (122)
Amygdaloid 7 d 7 S. 550 - 567 (17)
With calcite, quartz, prehnite, and copper, seams inclined 15° to the hole.
Trap 7 d 7 S. 567 - 672 (105)
Rather fine grained with chloritic slips to 612 ft. About 640 a 5 mm. mottling appears?; a chloritic slip at 14° to core may be nearly vertical.

(107) 13. Amygdaloid 7 d 7 S. 672-686 (14)
Well marked brecciated, with pink prehnite and copper at 677.
The correlation of 7 d 7 S. at 672 feet with 7 d 8 S. at 170 feet implies a dip of 31.5°, just about at right angles to the hole.

Manitou drill hole 7. 8. S. at 86 + 84. Elevation 570 A. L. S., Dip 55°.

1. Overburden (13) (13)

(105) 2. Ophite
Trap 7 d 8 S. 13 - 41½
Faintly ophitic with chlorite seams

(106) 3. Feldspathic ophite (?) (129)

Amygdaloid 7 d 8 S. 41½ - 57 (16)

Spotty with pink prehnite

Trap 7 d 8 S. 57 - 170 (113)

Fine grained, grey epidote to 66, then massive with chloritic seams at 10°, 26° and 45° to core (probably columnar joints at right angles to the dip) and mottling barely perceptible. This is presumably the same bed as 7 d 7 S. 550 - 672.

(107) 4. Feldspathic ophite (?) (102)

Amygdaloid 7 d 8 S. 170 - 177 (7)

Marked, with quartz crystals and prehnite

Trap 7 d 8 S. 177 - 272 (95)

Specked at 205, 216 - 234, faintly if at all mottled

(108) 5. Feldspathic ophite (132)

Amygdaloid ? 7 d 8 S. 272 - 294 (22)

To 277 specked, then glomeroporphyritic

Trap 7 d 8 S. 294 - 403 (109)

Similar beds are found in the Central mine Section Hole No. 4.

Many reddish seams at 32° to the core are probably nearly vertical.

From 338 - 364 it is very faintly mottled (3 mm.) and then grows finer to the base.

The tendency of the beds at this part of the column to be but little ophitic, and that only at the extreme bottom, with red glomeroporphyritic top was noted also at the Central mine flow 106.

(109) 6. Feldspathic ophite (4 mm.) (107)

Amygdaloid 7 d 8 S. 403 - 407 (4)

Pink seams here at 70.5° may be nearly parallel to bedding. The amygdaloid is coarse, with chlorite and calcite.

Trap 7 d 8 S. 407 - 510 (103)

Faintly ophitic,—at 460 feet, 3 to 4 mm. mottles.

(110) 7. Feldspathic ophite 7 mm. (149)

Amygdaloid 7 d 8 S. 510 - 517 (7)

Poor

Trap 7 d 8 S. 517 - 659 (142)

This is doleritic at 555, and has veins and pink seams and is the first well marked ophite for several hundred feet above it.

At 563,	573,	600,	632 ft. the mottles are
4–5,	7,	6–9,	5 mm.

Comparing these drill holes 8, 7, and 6, we see a progressive decrease in the size of the flows and more sediment toward the top. The lower flows are heavier, but still of the same type, with relatively coarse faint mottles close to the bottom of the flow.

Cf. Central mine flow 107

(111) 8. Amygdaloid 7 d 8 S. 659-668 (9)

Coarse, lying just above a seam 663-668 at 15° to the hole.

The thicker character of the beds in Hole 8 is noteworthy.

The thick beds at the top of 7 d 9 and bottom of 7 d 8 should be a topographic feature and is slightly.

Manitou drill hole 7. 9. S. at 9800 of section. Elevation 580. Dip 57°.

(112) 1. Ophite (9 mm.) (167+20?)
Trap 7 d 9 S. 42-209 (167) (190)
At 45, 82, 98, 130, 149, 175 ft. mottles are
2, 6, 6, 8-10, 8-10, 6 mm.
180, 192
4, 2-3 mm.

This does not show the top of the bed for which safely 20 feet more can be allowed, as the bottom bed in 8 is more ophitic than those above and this is more ophitic yet. It is natural to assume it to be the bed below the last in hole 7 d 8, and the dip derived is consistent (32.5°).
At 149 is coarsest and then finer.

(113) 2. Melaphyre (54)
Amygdaloid 7 d 9 S. 209-215 (6)
Poor
Trap 7 d 9 S. 215-263 (48)
Fine grained

(114) 3. Melaphyre (23)
Amygdaloid 7 d 9 S. 263-265 (2)
Red and white
Trap 7 d 9 S. 265-296 (21)
Feldspathic, fine grained.

(115) 4. Feldspathic ophite (53)
Amygdaloid 7 d 9 S. 286-292 (6)
Red and white marked
Trap 7 d 9 S. 292-339 (47)
At 292 and 323 feet the faint mottles are
2 and 3 mm. respectively

(116) 5. Labradorite (?) ophite (41)
Amygdaloid 7 d 9 S. 339-345 (6)
Trap 7 d 9 S. 345-379 (35)
Fine grained with large phenocrysts that remind one of the Kearsarge foot, greenish, faintly ophitic.

(117) 6. Labradorite (?) ophite (48)
Amygdaloid 7 d 9 S. 379-385 (6)
Fine grained, with green pseudomorphs of porphyritic crystals apparently, many seams at 71.5°, some at 18.5°.
Trap 7 d 9 S. 385-427 (42)

(118) 7. Melaphyre (19)
Amygdaloid 7 d 9 S. 427-432 (5)
Chloritic and epidotic
Trap 7 d 9 S. 432-446 (14)
Base uncertain

(119) 8. Melaphyre (15)
Amygdaloid 7 d 9 S. 446-449 (?3)
Trap 7 d 9 S. 449-461 (12)
It is a question if this is a separate flow.

(120) 9. Feldspathic ophite . (77?)
Amygdaloid 7 d 9 S. 461-462 (1)
No core 7 d 9 S. 462-463 (1)
Amygdaloid 7 d 9 S. 463-474 (11)
With spots of trap
Trap 7 d 9 S. 474-538 (64)
Many pink (laumontite?) seams at 45° or 50° with core.
Faintly mottled, up to 10 mm?
This bed is very likely disturbed and incomplete.

(121) 10. Melaphyre (24)
Amygdaloid 7 d 9 S. 538-550 (12)
Red and white to 541, then chloritic
Trap 7 d 9 S. 550-562 (12)
With pink seams nearly parallel to the hole.

(122) 11. Melaphyre (45)
Amygdaloid 7 d 9 S. 562-573 (11)
Only chloritic from 567-573
Trap ? 7 d 9 S. 573-607 (34)
(All fragments, probably the drill was following a chloritic seam.)

(123) 12. Amygdaloid 7 d 9 S. 607-617 (10) (33)
Red, white and green with pseudomorphs of phenocrysts, a chloritic amygdaloid.
Trap 7 d 9 S. 617-640 (23)

(124) 13. Amygdaloid 7 d 9 S. 617-640 (23) (48)
Red calcitic above, green chloritic below.
Trap 7 d 9 S. 651-688 (37)

(125) 14. Melaphyre (13)
Amygdaloid 7 d 9 S. 688-693 (5)
Red and calcitic to 691, then green
Trap 7 d 9 S. 693-701 (8)

(126) 15. Melaphyre (21)
Amygdaloid 7 d 9 S. 701-706 (5)
Trap 7 d 9 S. 706-716 vein? or 722 (16)

(127) 16. (18)
Amygdaloid 7 d 9 S. 722-725 (3)
Trap 7 d 9 S. 725-740 (15)

(123) 17. Feldspathic ophite (43)
Amygdaloid 7 d 9 S. 740-746 (6)
Trap 7 d 9 S. 746-783 (37)
Faintly ophitic as at 519 from 766-775

(129) 18. (23)
Amygdaloid 7 d 9 S. 783-787 (4)
Trap 7 d 9 S. 787-806 (19)
Chloritic amygdules 7 d 9 S. 791-798

(130) 19. Amygdaloid 7 d 9 S. 806-811 (5)
Marked, with prehnite, calcite and feldspar
Trap 7 d 9 S. 811-850 (38)
Coarsest, faintly mottled at about 830 ft
Finer to 850, where there is a seam.

(131) 20. Amygdaloidal melaphyre (19)
Amygdaloid 7 d 9 S. 850-865 (15)
Trap 7 d 9 S. 865-869 (4)
Bottom contacts at 66°

(132) 21.

Amygdaloid 7 d 9 S. 869-889 (20)

Contact at (9:4) 66° to core

The Bohemia conglomerates should, with the strike given on Penhallegon's map, pass about 800 feet south of 7 d 9 S. The elevation where the railroad crosses the conglomerate at the center of Section 30 is 504, while the elevation of a point on the line of M. 7. west is 570. The non-appearance in Hole 9 implies a steeper dip or more southerly strike of the conglomerate. But the bottom of this hole 7 d 9 S.] certainly cannot be far above it.

The No. 3 section supplements No. 7 very desirably to the north, and is the only one which gives a complete cross-section of the Greenstone, confirming my previous view as to the character of this as one immense flow.

Manitou Mining Co., Sec. 3. (See Fig. 29 in envelope). Runs S. from E-W center line of Section 10, T. 50 N., R. 30 W. 175 paces west of the east line of Sections 10, 15, 22. This is 6212 feet north of 0 of the line, and Section 7 runs south along a line 1140 paces west of the east lines of Sections 13, 24 and 25. The main examination has been of Section 3. The holes put down at a dip of about 70° to the south are so nearly at right angles to the formation that no correction from depths for thickness is needed.

Manitou 3 drill hole 5 N. Elevation 542 feet above Lake Superior. Di p69°. 6183′ N. of 0 of M. 3.

0-16 surface

1. Porphyrite 3 d 5 N. 16-53 (37)
   Light colored, feldspathic, of "ashbed diabase." Tobin porphyrite type. A seam dips 75.5° with the hole (?36°).
2. Porphyrite
   Amygdaloid 3 d 5 N. 53-56=3 (30)
   Chloritic, open to 61 and from 70-79 but not a new flow.
   Trap? 3 d 5 N. 56-83=27
3. Feldspathic ophite?
   Amygdaloid 3 d 5 N. 83- (79)
   With a little copper
   Trap 3 d 5 N.-162
   The trap is very solid with very few seams (at 26° or so to the hole, i. e., nearly vertical), from 116-137 a very faint coarse mottling like a feldspathic ophite, at 137 3 mm?, the base is red and glomeroporphyritic. Cf. Eagle River (Marvine) 82 and 84 (Fig. 34)
4. Sediment (sand) at contact 3 d 5 N. 162
   Probably Marvine's Cg. 16, the Pewabic West. Cf. Eagle River 78 to 85.

Addition figures show thickness above Mesnard bed.

3. Porphyrite (11) (506)
   Amygdaloid 3 d 5 N. 162-165
   Trap 3 d 5 N. 165-173

6. Melaphyre
   Amygdaloid 3 d 5 N. 173-176 (11) (495)
   Prehnite and calcite
   Trap 3 d 5 N. 176-184
   Blotched.
7. Ophite
   Amygdaloid 3 d 5 N. 184-202 and at 204 and 222-226 (147) (484)
   Trap 3 d 5 N. 226-331
   At 232 to 241 there is fissuring about parallel to the hole and the trap looks decomposed. At 250 there are seams at 56.5° and 31° with the hole, at 263 there is a doleritic spot, at 313 there is a large rhyocrystal 10 x 5 mm. The mottling is 18, 10-12, 8?, 2-3 mm., and fine respectively at 280, 267, 313, 327, 324.
8. Amygdaloid 3 d 5 N. 331-337? (11) (277)
   Trap 3 d 5 N. 337-342
   Contact at 331, rhyocrystals at 334, amygdaloid at 337-338, just a spot?
   These remind one of beds just above the Quincy mine.
9. (8) (276)
   Amygdaloid 3 d 5 N. 342-344
   Trap? 3 d 5 N. 344-350
   A very marked contact with a dip of 71.5° against the core.
10. (19) (269)
   Amygdaloid 3 d 5 N. 350-363
   Trap 3 d 5 N. 363-369
   This is a very well marked amygdaloid with a dark green base, white and green amygdules, then redder.
11. Amygdaloid conglomerate?
12. Ophite
   Amygdaloid 3 d 5 N. 369-389 (101) 250
   Red, fine grained.
   Trap 3 d 5 N. 389-470?
   Fine grained, dark trap with chloritic slickensiding parallel to the hole and very fine mottling
   2, 2, 1½, 1, ½ mm.
   at 414, 426, 451, 461, 466 ft. respectively.
13. Glomeroporphyrite (30) (149)
   Amygdaloid and trap 3 d 5 N. 470-500. The amygdaloid is not well marked and the contact with the overlying uncertain. There are small chloritic amygdules about 4 mm. across and pink feldspar lath sections 2 mm. long up to 4 mm.
14. Feldspathic melaphyre (41) (119)
   3 d 5 N. 500-541
   The contact is marked, then there is a coarse reddish feldspathic bed with green amygdaloid spots.
15. Porphyrite (30) (78)
   Amygdaloid 3 d 5 N. 541-560
   Quartzose, glomeroporphyritic, streaked with trap.
   Trap 3 d 5 N. 560-571.
   Trap blotched with chlorite, with pink feldspar.

16. Porphyrite, amygdaloidal. (48) (48)

Amygdaloid 3 d 5 N. 571-579-619

Glomeroporphyritic, a sedimentary contact with an angle of 71.5° against the core at the base.

17. Sedimentary contact at 3 d 5 N. 619. Cf. the Mesnard epidote (0)

18. Amygdaloidal melaphyre gush of the underlying?

Amygdaloid	3 d 5 N.	619-624 contact?	
"		624-629	(33)
"	trap	629-642	
Trap		642-794?	

Amygdaloidal spots at 654 and 657. Compact, getting darker, coarsest about 671 2 mm. ophite, then finer and darker to the end. Presumably the bottom of this bed and the top of the next are cut by numerous chlorite seams nearly parallel to the hole between 694 and 794, which imply faulting.

19. The Greenstone (1130)

Top not visible, cut by fault?

3 d 5 N. 794-833; 3 d 4 N.; 3 d 3 N. 1 to 616; 3 d 2 N. 1-296.

This grows suddenly and irregularly very coarse, and the easy way to account for it is to suppose that a fault zone, such as is known to be heading this way from the Manitou No. 1 shaft, has crossed it. If it does belong to the No. 1 shaft fault set, it strikes 20° to 25° W. of N. and hades E. as usual, so that the hole is at first on the upper east side of the fault, then passing through in accordance with the more common rule that the east side is thrown down or back, the hole meets suddenly relatively deep horizons. A normal strike fault or slide would, however, produce the same effect, but the direction of the chlorite slips between 694 and 797 seems to rule this out.

An almost identical change in grain with chlorite slips occurs just at the top of 3 d 4 N., and the fault at Manitou No. 1 shaft would, if it did not swerve, apparently run west of 3 d 4 N. But if we suppose that it is the same fault zone which disturbs 3 d 4. N. at 6-44 and 3 d 5 N. at 694-700, a hade of 45° to the E. would be indicated and that is hardly likely.

Similar chlorite seams occur in the other holes, and as in 3 d 2 N. 249-257+ are often associated with abnormal changes of grain.

This Greenstone also forms the whole of Hole 3 d 4 N. most of Hole M. 3. 3 N. and a large part of Hole 3 d 2 N. It is also touched in Manitou 39, 41, 43, and the Medora holes 13 and 14 traverse it in part. These correlations may be made very surely. But if we are not mistaken, it was also traversed in the Isle Royale drill cores, Hole 6, 91-363, and there are many field exposures. It therefore furnishes an unusual chance to study the variation of the grain. Beside the faulting above mentioned, however, there are other difficulties. When the size of the augite patches is more than half the width of the core, say over 10-15 mm., the predominance of sections not showing the full dimensions of a mottle becomes more marked, while at the same time the mottling itself becomes very much less defined. Estimates of the grain based on the mottling in drill cores are therefore less certain. Thin sections are, of course, out of the question, and pock marked weathered surfaces make the most pronounced and best defined pattern. (See Plates II and III.) I am not

sure, however, how my estimates of the coarseness with them compare with those obtained in other ways

We note in 3 d 5 N., chlorite seam at 694-794.

Grain 2, 4, 5, 6–7, 7, 8, 7–10 mm. respectively at
794, 808, 813, 818, 823, 828, 830 feet.

In 3 d 4 N., chlorite seam, 2–3, 3, 3–5, 7, 10–12, mm.,
respectively at 6–44, 56, 61, 65, 74–80, 99, feet
and 30?, 12, 12? 8+, 10–12+ 8, 15, 25? mm.
at 99, 113, 130, 161, 170, 218–222, 273, 342, ft.
and 15, 16, 15–40? 20, 15 mm.
at 403, 489, 554, 556 ft.

In 3 d 3 N. mm. 40–60, 40, 40, 45, 25? (or 50 center to center)
respectively at 35, 52, 65–113, 113–156, 156–246, feet;
also 30, 40, 30, 50? 20, 15, 12–15, mm. resp.
at 240, 246–288, 288–332, 426–467, 469, 498, 511, feet;
also 8, 8–10, 7, 5, 3, 2, ½, mm. 0 resp.
at 525, 532, 550, 565, 589, 601, 606, 615 ft.

This would be a mean gradient in 3 d 3 N. of .00037, about 1 mm. in 9.1 ft., 1 inch knobs in 225 ft.

In 3 d 2 N. 30? 40? 12, 10, 8–4, 6, 3, 0 mm.,
resp. at 6–56, 104, 140, 180–188, 188–250, 250, 257, 290

This would mean a mean increase of about 1 mm. in 10 ft.

If we compare 3 d 3 N. with the Mandan holes we find that they have mean rates of increase (A) of 1 mm. in 8.6 ft. and 1 in 9.9 ft. respectively. This is quite as close an agreement as one would expect from the observations as the probable and possible error in each series is much greater than the difference in the different series. At the Isle Royale, however, the rate of increase I made from thin sections was only about half as great, .0002. This would indicate that the temperature of the magma at the time of coming to rest was higher[1] on the Isle Royale though still not over say 10% above the temperature of consolidation. It is possible that the very thick parts of the flow continued in motion and so stirred up to a lower mean temperature more readily than the thinner. Or it may be that the Greenstone, though thicker on the point, is farther from its source and so in flowing had more time to cool.

But on re-measuring the mottles on the Isle Royale drill cores with the eye, rather than the patches of augite in thin section, I find my results uniformly larger, especially for the coarser mottlings, where evidently the thin section does not give enough to show the pattern, and this will reduce the discrepancy very materially, perhaps entirely.

Manitou 3 drill hole 4 N. Elevation 573′ above Lake Superior. Dip 69°. 4,300′ N. of 0 of M. 3., and 440′ N. of the S. line of Sec. 10, T. 50 N., R. 30 W.

(19). All in the Greenstone. The mottling has been given above. Doleritic streaks occur at 74 (7 mm. augite, 3 mm. feldspar), at 99 (30 mm. augite, 6-8 mm. feldspar), at 161 (5 mm. feldspar), at 218-222 (6-8 mm. feldspar), at 250-257 (12 mm. feldspar), at 301, 421, 436, 457, 489 large porphyritic crystals (rhyocrystals) of fresh bytownite (labradorite) occur, at times not less than 15 mm. long.

The grain does not seem to vary from center to margin of a particular

[1]See Chapter IV.

doleritic streak (Marvine's light type of diorite) but does seem to be rather coarser in the thick streaks and in the center of the flow.

The chlorite slips occur at many points and in many directions, often nearly vertical, parallel to the hole, so from 6-44, again near 170, and at 285, 491-544 (prehnite,—at 382 is a prehnite seam also); and at 589.

Manitou 3 drill hole 3 N. Elevation 625′ above Lake Superior. Dip 67°. 2746′ N. of No. 3, 365′ S. of the N. line of Sec. 15.

(19). In the Greenstone 3 d 3 N. 1-615 (630+ (40 to 60 x 9) 1130

Occasional large feldspar crystals 21 x 4½ mm., 12 x 2 mm., at 57 is a seam at an angle of 24° with the hole, at 396-411 are heavy seams of chlorite, again at 543-545 is a chlorite seam which brings out the ophitic pattern beautifully, see photograph (Pl. IV. b) running nearly parallel to the core. From 1 to 467 the pattern is too coarse and faint to measure accurately. At 156-202 it is about 50 mm. from center to center of the faint mottles marked by an absence of coarser green spots, perhaps altered olivine. At the very beginning 35, the mottles are 40-60 mm. across.

If then we assume the center of the flow at 3 d 3 N. 120, 510 feet from the bottom, with mottles of say 56 to 46 mm. we have a thickness which agrees with the indications of the surface exposures and dips and the drill holes, a mottling which agrees with the indications in this hole and the one north so far as it can be made out at the center, with the pockmarking (Pl. III) due to weathering and also with general rate of increase assumed to continue uniformly to the center. This might imply that the lava temperature was not more than 10% above that of consolidation, while the exceptionally large rate of increase may show that the excess was even less, only about 2% above. The occasional sparse rhyocrystals of labradorite found show also that the temperature of the moving lava can not have been above 1400° C., while the temperature of consolidation was probably between 1000° and 1100° C.

(20). *Allouez conglomerate.* (25)

Clay fluccan slide at 615

Conglomerate 3 d 3 N. 615-640

Copper at 630. Shades off into a weathered and decomposed top of a trap.

(21). Trap not marked amygdaloidal 3 d 3 N. 640-657.

Manitou 3 drill hole 2 N. Elevation 638′ above Lake Superior. 1818′ N. of M. 3, 493′ N. of the crest of the Greenstone Range (which is 693′ A. L. S.) and 965 from the center line of Section 15. Dip 67°.

(19). The Greenstone (1130+)

Trap 3 d 2 N. 1-290+

Mottles (as given above) from 30 to 40 mm. down, porphyritic labradorite crystals 15 mm., in one case 35 mm. The chloritic seams occur at 100-145, 249, etc. Pink seams are more often nearly across core.

20. Allouez conglomerate

3 d 2 N. 290-315 (25)

Felsitic, dip 21.5°

21. Feldspathic melaphyre (15)
3 d 2 N. 315-330 Cf. Mandan d 14. 582-616
13. 220-

22. Ophite, feldspathic (80)
Amygdaloid 3 d 2 N. 330-349
Pink and white to 333 and occasional red bordered amygdules to 349.
Trap 3 d 2 N. 349-410
More or less seamed more or less parallel to the bedding. Mottles 3-4 mm. at 393.
Cf. Mandan d 14. 616-673
13. 220-310 (5 mm. at 280)
(95)

23. *Medora lode.* (26)
Amygdaloid 3 d 2 N. 410-414
Trap 3 d 2 N. 414-436
Fine grained, brecciated 3 d 2 N. 433-436
This may not be an independent flow, but cf.
Mandan d 14. 673-725
13. 310-326 (121)

24. Feldspathic ophite (100)
Amygdaloidal trap 3 d 2 N. 436-441 *Manitou lode?*
Trap 3 d 2 N. 441-536
Coarse feldspathic with faint mottles up to 5 mm., at 485 a spot of amygdaloid, toward base prehnite seams across the hole and finer.
(221)

25.
Amygdaloid 3 d 2 N. 536-538 (30+)
Trap 3 d 2 N. 538-566+

Manitou 3 drill hole 1 N. Elevation 572′ above Lake Superior, 570′ N. of 3 and 370′ S. of the base of the Allouez which is 600′ above Lake Superior. It begins in an exposure made by the rather massive trap 24.

(24). Feldspathic ophite
3 d 1 N. 4-46. Coarse faint mottling 4 mm. at 23.
(221)

(25). Feldspathic ophite (38)
Amygdaloid 3 d 1 N. 46-48=M. 3 d 2 N. 536-538
Trap 3 d 1 N. 48-84?
Coarse mottled 5 mm. at 67-74
Perhaps not a separate flow. (259)

26. Feldspathic ophite (43)
Amygdaloid? 3 d 1 N. 84-85
Amygdaloid trap 3 d 1 N. 86-96
Trap 3 d 1 N. 96-127
Coarse, faintly mottled at 104, then finer, at 119 green forms like porphyritic crystals on a red ground, and a well-marked base (302)

27. Ophite Mandan ophite (a) (73)
Amygdaloid 3 d 1 N. 127-137
Marked, good looking, prehnitic.

Trap 3 d 1 N. 137-200
The mottles are 3, 5, 5 mm. respectively
at 149, 168, 178, feet.
The mottling is so coarse close to the base of this and the top of the next, I take them to be close following gushes representing the Mandan ophite, or else fault repetitions. (375)

28. Ophite Mandan ophite (b)
Amygdaloid 3 1 N. 200-203 (59)
Marked with prehnite and copper. (434)
Trap 3 d 1 N. 203-259
5 mm. mottles at 218

29. Ophite, feldspathic (32) (466)
Amygdaloid 3 d 1 N. 259-263
Trap 3 d 1 N. 263-291
Faintly mottled, coarsest about 276

30. Ophite, (36) (502)
Amygdaloid 3 d 1 N. 291-307½
Trap 3 d 1 W. 307½-337

31. Ophite (108) (610)
Amygdaloid 3 d 1 N. 337-339
Trap 3 d 1 N. 339-445
Grows coarser to 415 (5 mm. mottles)

32. The Houghton conglomerate 3 d 1 N. 445-473 (28) (638)
Rather basic, but with felsite pebbles to 446, then a regular felsite conglomerate. At 455 dips in shaly bands are at an angle with the core of 71.5° and 65.5°. It gradually passes into an amygdaloid conglomerate with a dark red matrix and dark fragments of scoria.
The distance below the Allouez is
at the Mandan and Medora (576)
at the Central (689)

33. Ophite (66)
Trap 3 d 1 N. 473-539
Cf. M. 3. 69-131 (62)
Amygdaloidal at top?
Cf. Mandan d 3. 190-265
1. 121-185
Mottling to 2-3 mm. at 500, then finer (66)

34. First belt below Houghton (11)
3 d 1 N. 539-550 (77)
Amygdaloid conglomerate and amygdaloid
Cf. M. d 3 131-141+

35. (24) (101)
Trap 3 d 1 N. 550-574
35, 36 and 37 belong together. Cf. Mandan d 3. 265-339. Cf. Mandan d 3. 141-202
Fine grained (61)

36. Ophite (31) (132)

Amygdaloid 3 d 1 N. 574-577. Second probably not independent flow.
Cf. M. 7 d 1 N. 125-133 (50)
Trap 577-605
Mottles 2 mm. at 590, then finer. 35, 36 and 37 are closely allied like 16, 17 and 18 at the Empire.

37. Ophite (84) (216)

Brecciated amygdaloid 3 d 1 N. 605-618. Third flow.
Cf. M. 7 d 1 N. 170-180+ (80)
M. 3 202-293 (91)
Trap 3 d 1 N. 618-689
Mottles are 2, 2 to 3, 1 mm. across respectively
at 646, 661, 676 ft.
Cf. Medora d 3. 339-461

(38). Montreal lode

Brecciated amygdaloid 3 d 1 N. 689-699
Cf. M. 7 d 1 N. 250-256
Brown and white.
This is the fourth amygdaloidal (or amygdaloid conglomerate) bed below the Houghton, or third if 574-577 be not counted, as may be more proper.

In the Montreal shaft No. 1 there was a pocket of rich copper rock at the top and 1st level, but at the 350-foot level there was nothing. The shaft was crossed by many seams down below and in the 1st level 390 feet to north. The accumulation of copper is then quite likely associated with a cross-fissure.

Manitou drill hole 3. 1780′ N. of the S. line of Sec. 15, T 58 N., R 30 W. 502′ above Lake Superior. Dip of the hole 65°. Dip of the bed on the Houghton 26°. On the Calumet 25¾°.

(31). Trap d 3. 25-53

(32). Houghton conglomerate d 3. 53-69
Felsitic 53-58, then red and white and black.
Amygdaloid conglomerates.

(33). Ophite 2 mm.
Trap d 3. 69-131
Mottles are 1, 2, seamed across core 1 mm. respectively
at 90, 104, 121 feet

(34). Amygdaloid conglomerate d 3. 131-141
Marked, brecciated, characteristic red or brown appearance.

(35 & 36). Ophite 2 mm.
Trap d 3. 141-202
There seem to be two beds in 3 d 1 N., and here it is finer with a seam of amygdaloid and *copper* at 190, but the mottling continues, being 2 mm, and 1 mm. at 174 and 197 respectively.

(37). Ophite 3 mm.
Amygdaloid and breccia d 3. 202-231
Trap d 3. 231-293
The mottles are 2 mm and 2-3 mm. at 257 and 273 respectively.

(38). Montreal lode and ophite foot {M. d 3. 293-331 (73)
Amygdaloid and breccia {M. 3 d 1 N. 689-699+
Trap d 3. 331-366
At 331 the change is rather sudden, (possibly due to faults on chloritic seams) to 2 mm. ophite mottling, increasing to 3 mm. at 345.

(39). Ophite 2-3 mm. (62)
Amygdaloid d 3. 366-382
Trap d 3. 382-428
Decomposed and seamed to 393. Mottles up to 2-3 mm.

(40). Ophite 3 mm. (82)
Brecciated amygdaloid d 3. 428-443
Well brecciated, perhaps even an amygdaloidal conglomerate, with much calcite.
Trap d 3. 443-510
The coarsest mottles (3 mm.) just above 488.

(41). Ophite (72)
Amygdaloid d 3. 510-512 poor
Trap d 3. 512-582. At 538 1-2 mm. mottles, *many chlorite seams.*

(42). Ophite 7 mm. (167)
Amygdaloid brecciated with trap d 3. 582-620
Trap d 3. 620-749
Ophite mottling varying from 1 to 3 mm. in the same core, at 645 3 mm., and between 651 and 693 coarsest, 6-7 mm.

43. Ophite (60+)
Amygdaloid d 3. 749-758
Well-marked brown and white, seam nearly parallel to hole between it and trap.
Trap d 3. 758-809. Mottles up to 3-5 mm.
3.18 219-271 (52) 3.2 332-86 (54); 7 d 1 S. 695-758 (63); 7 d 2 S. 200-250 (50); Empire flow 25 (63) etc.

44. Calumet conglomerate d 3. 809-816 (7)
With felsite and amygdaloid pebbles, and yellow epidote and calcite, gradually more basic.
Base below base of Houghton conglomerate (816 minus 69) (747)

45. To 829 decomposed fine grained trap with some amygdules and many chlorite slips.

Manitou 3 drill hole 1 S. of M. 3 1142′. 480′ above Lake Superior. Dip 65°; of the Calumet conglomerate 26°.

This exposes no beds not touched in d 3. or 3 d 2 S. We have simply:

(41). A 3 mm. ophite.

(42). 3 d 1 S. 52-74 Amygdaloid, then trap (mottling 7 mm. between 139 and 179) (167)

(43). 3 d 1 S. 219-235. Amygdaloid with *copper* in the hanging, then trap (52)

(44). 3 d 1 S. 271-275 Calumet conglomerate. Felsitic to 278, to 283 amygdaloid. (7)

(45). 3 d 1 S. 283-357 Epidotic, then ophite (4 mm. at 328)

(46). 3 d 1 S. 357-371 Amygdaloid, then ophite (3 mm. at 365) then nearly vertical seam to 390.

Manitou 3 drill hole 2 S. S. of M. 3. 1575′, 130′ N. of a small shaft striking the Calumet foot through 25′ of drift, and 215′ N. of the soutn line of sec. 15, T. 58 N., R. 30. W.; 480′ above Lake Superior. Dip of hole 65°, of beds about 26°, by correlation and observation.

(42). Fine grained trap seamed at an angle of 73.5°.

(43). Amygdaloid 3 d 2 S. 34-38 (54)

Brown and white, then green, brown and white, and at 41 in the foot, seams of prehnite with copper.

Trap 3 d 2 S. 38-86.

Mottles 3 mm. at 61, 2 mm. at 79, and redder toward base. A persistent and uniform bed here and elsewhere.

(44). Calumet conglomerate (14)

Felsitic 3 d 2 S. 86-88

Amygdaloid 3 d 2 S. 88-100

The dip is well marked 14. 7:30 exactly 26° agreeing with correlations.

(45). Ophite (72)

3 d 2 S. 100-172

A decomposed trap with a chlorite seam at 5° to 10° to hole at 134 and 168. Mottles 1 mm. at 116, 3 mm. at 134-147, then finer, 1 mm. at 168.

Cf. M. 3 d 1 S. 283-357 (74)
7 d 1 S. 260-320
M. d 3 S. 816-829+

Empire flow 27 (69)
Clark flow .29?

46. Amygdaloidal conglomerate and ophite (72)

Amygdaloid? 3 d 2 S. 172-175. (144)

At the top a narrow band of amygdaloid conglomerate not found elsewhere, and the line between that and the amygdaloid not marked.

Trap 3 d 2 S. 175-244.
There is a prehnite seam nearly straight across the core (77.5°)
The coarsest mottling is 2-3 mm. near 214.
7 d 1 S. 320-390. Empire flows 28 & 29?

47. Amygdaloidal conglomerate and ophite (90)

(234)

Amygdaloid? 3 d 2 S. 244-250

Analcite occurs. Red and green fragments occur imbedded in a prehnitic ground. There may be a few inches of the amygdaloid conglomerate which is much like that at 172.

Trap 3 d 2 S. 250-334

Mottles are 3 mm. at 280; 4-5 mm. at 298; 1 mm. at 320, near which is a chlorite seam parallel to hole, near vertical?

7 d 1 S. 390-480 (90) Empire f. 29?

48. Ophite (Calumet amygdaloid and foot?) (125)

359

Amygdaloid 3 d 2 S. 334-338
Trap 3 d 2 S. 338-459 poor

Ophite up to 4-5 mm. mottles down to 376, at 408 7 mm. mottles matching Empire hole 4.880 f. 80, at 423 4 mm. At 380, 418 and beyond 423 are heavy chlorite seams and from 452 the base is much brecciated. 7 d 1 S. 480-587 (107)

Empire f. 30 (140), M. 7 d 2 S. 35-145 (110)
Mandan 10. 567-694 (6 mm.)

In the figure (29) the Calumet and Osceola amygdaloids are placed lower and there is some uncertainty as to their exact correlation, depending somewhat upon whether one correlates from the Kearsarge conglomerate below or the Calumet conglomerate above.

49. Ophite (Osceola amygdaloid and foot .3). (86)

Amygdaloid 3 d 2 S. 459-467 (8)

Prehnitic, conglomeritic.

Trap 3 d 2 S. 467-545

Mottles	3-4,	1,	½ mm.	
at	494-509,	526,	534	with brecciated base.

Cf. 7 d 1 S. 587-612 (25)

7 d 2 S. 145-160-255

Empire f. 31 (948-970+?) to f, 33

Mandan 10. 694-784 (83) a 3 mm. ophite with porphyritic feldspar?, a doleritic ophite

(50). Ophite

Amygdaloid	3 d 2 S.	545-559	
Cf.	3 d 3 S.	73- 85-172	(91)
	Mandan	694-784	(81)
	Empire f.	34	

Frontenac 3 drill hole 3 S. 2624′ S. of M. 3, 823′ S. of N. line of Sec. 22. Elevation 495′ above Lake Superior. Dip of hole 65°. Of beds 27°. (445)

Surface 20

(49). Trap 3 d 3 S. 20-73 (53+40+)

Begins in bed 49 with a 4 mm. mottling at 25, 2-3 mm. at 49, 1 mm. at 65. From 71-73 is red and brecciated.

50. Feldspathic ophite. Osceola amygdaloid and foot.

Amygdaloid 3 d 3 S. 73-85 Cf. 3 d 2 S. 545-559 (91)

Prehnitic and conglomeritic.

Trap 3 d 3 S. 85-172 (536)

Mottles	2,	2-3,	8,	4?,	2 mm.
at	101,	115,	122,	140,	155

There are chloritic seams at 45° at 155, then it is finer and somewhat brecciated. For correlations see above 3 d 2 S. Do these chloritic seams mean dropping out beds corresponding to Empire 32 to 33?

51. Doleritic ophite (153)

Amygdaloid Frontenac 3 d 3. S. 172-175 (689)

Poor

Trap 3 d 3 S. 175-325

Coarse feldspathic faint 4 mm. mottles 197-247, at 230 5 mm, 257 7 to 12 mm., 275 7 mm. Doleritic at 203, 204, 209, 214-216 (feldspar 6 mm. with calcite and chloritic interstices), and 258. Cf. 7 d 2 S. 255-263-450 with a narrow amygdaloid reported at 340-345, probably one of the dole ritic streaks. Also Empire flow 35 (141), which is also doleritic and about the same size, and Mandan d 10. 784-925 (129).

52. Ophite (21)

Amygdaloid 3 d 3 S. 325-327 (710)

Calcareous amygdaloidal trap to 333.

Trap 3 d 3 S. 327-346. Mottling 1 mm. at 337.

53. Ophite (103)

Amygdaloid 3 d 3 S. 346-353 (813)

Marked brecciated numerous seams at an angle of 66° with core.

Trap 3 d 3 S. 353-449

At first fine grained with coarse chloritic, and calcite and laumontite amygdules, and remains apparently fine grained with occasional amygdaloid spots throughout, seams making an angle of 10° to the core, presumably nearly vertical, with pink laumontite or calcite fillings are displaced by others which are perpendicular to the core and presumably nearly parallel to the dip, the north or upper side being thrown west. This would be the effect of a down slide on a north or northeast striking vertical seam.

54. Doleritic ophite (181)

Amygdaloid 3 d 3 S. 449-451 (994)

Amygdaloidal trap 3 d 3 S. 451-471

Fine grained, spotted, with occasional red bordered amygdules.

Trap 471-630

Grows in general coarser but at 548, 500, 551 doleritic apparently finer, also at 565 and 584. Mottles 5 mm. at 585, 3 mm. at 628. Pink seams at 14°½ to core. If these are vertical also seams at 66° to core, may strike N. 70° W. dip 70° to N. nearly perpendicular to them. Much seamed near base.

This is the first bed in Hole 3 d 4 S. -66
It occurs also in 7 d 3 S. 165-303
Mandan 8. 48-158
10. 1050-1220?
Empire f. 36 and 37, especially 36.
Clark hole 4

Characteristic of this belt is its amygdaloidal character, and the doleritic streaks, while the mottling is ill-defined, so that there is a temptation to consider it several belts or flows.

55. Amygdaloidal melaphyre (independent?) (26)

Amygdaloid	3 d 3 S.	630-635
Trap	3 d 3 S.	635-640
Amygdaloid	3 d 3 S.	640-656

56. Kearsarge conglomerate (1010)

Felsitic conglomerate 3 d 3 S. 656-669 (13)

Foot brecciated, passing into fine grained ophite (1023)

For the distance to the Calumet compare:

Mandan d 10.	194-1230 (900-940)	distance	in	thickness
Empire	(744)	"	"	"
Manitou 7	(1080)	"	"	"
Central	(1190)	"	"	"

Around Calumet the distance is commonly 930-994. Out to the Empire the distance is remarkably persistent. There is some loss at the Empire by faulting or otherwise, unless (as is quite likely, see Fig. 24.) Holes 2 and 4 do not lap, and the dip is about 45°. With such a dip the distance from the Calumet to the Kearsarge would be 1050.

Frontenac 3 drill hole 4 S. 3878′ S. of No. 3 hole and 2064′ S. of N. line of Sec. 22. El. 518′ above Lake Superior. Dip 65°; of beds 26.5°.

(54). Ophite at 37 3 mm. mottles, at 50 2 mm. mottles 30-66

(55). Amygdaloidal melaphyre (40)

Amygdaloid 3 d 4 S. 66-68
Trap 3 d 4 S. 68-106

Chloritic to 75, then faintly ophitic, growing finer.

(56). Kearsarge conglomerate 3 d 4 S. 106-121 (15)

The last foot is of basic material. At 118 a good dip is 80.5° against the core.

(57). Kearsarge foot ophite (83)

Trap 3 d 4 S. 118-201

Weathered from 150-158, much seamed at an angle with the core of 15°. The mottling is at 185 4 mm., at 197 1-2 mm. Usually thicker. Belts 58 and 59 probably often merge? Empire f. 39.

58. Ophite, feldspathic (91) (174)

Amygdaloid 3 d 4 S. 201-202 Poor
Trap 3 d 4 S. 202-293

Faintly mottled (5 mm.) doleritic at intervals 223-244, with 3-4 mm. mottles at 270. Empire f. 40.

59. Sediment and trap? 3 d 4 S. (293-342-) (49) (223)

60. From 296-304 is much veined and probably a repetition of the bed above. At 324-326 is a sediment, a clasolite perhaps, but green, epidotic as well as red, with a dip of 80° to 77° against core.

61. Amygdaloid 3 d 4 S. 342-344 (5) (228)

Glomeroporphyritic base and amygdaloid.
Trap ? 3 d 4 S. 344-347.

62. Amygdaloid conglomerate 3 d 4 S. 347-350 (3) (231)

63. Feldspathic ophite 3 d 4 S. 350-376½ (26½) (257½)

3 mm. mottles at 367.

64. Sedimentary contact at 376½

From 293-376½ is not easy to define owing to the faulting and the irregular mixture of sediment and trap. Though it may be in part clasolitic, there is evidently at least one well-marked sedimentary horizon, a premonition of the Kearsarge. Cf. Empire f. 41, also Mandan d 8. 574.5-589, where the intervening traps are much thicker, also C. & H. D. flows 5 & 6.

65. Feldspathic melaphyre (62½) (320)

Amygdaloid 3 d 4 S. 376½-377
Trap 3 d 4 S. 377 -439

Seamed at 389, with a bomb near 406.

66. Ophite (10 mm.) (225) (545)

Amygdaloid 3 d 4 S. 439′-444′
Trap 3 d 4 S. 444′-664′

From 450-455 is a seam of calcite quartz and *copper* in the feldspathic ophite, which grows coarser up to 540-568, and grows darker green chloritic with *copper* in the chlorite at 575.

The mottles are up to	8,	10,	8,	5,	2 mm.
respectively at	503-513,	540-568,	575,	615,	659

This is at the top of 5, is also probably the same as Central f. 46 There is nothing so large at the Mandan except the flow directly under the Kearsarge. At the Empire section compare f. 42.

67. Sedimentary bottom contact (1)
Frontenac 3 d 4 S. 664-665 3 d 5 S. 71-74 (546)

68. Melaphyre
Trap 3 d 4 S. 665-700 (25)
Frontenac 3 d 5 S. 74-105 (31) (571)

69. Ophite (15+)
Amygdaloid Frontenac 3 d 4 S. 700-704
Trap 3 d 4 S. 704-715+
Mottled up to 2 mm.
Frontenac 3 d 5 S. 105-112-164 (59)

Frontenac 3 drill hole 5 S. Location 5150′ S. of No. 3 hole. El. 523′ above Lake Superior. Dip of hole 65°; of beds 27½°. By correlations on the sediment at 72 a dip of even 34° might be inferred.

(66). Ophite
Trap Frontenac 3 d 5 S. 39-66
Poor amygdaloid 3 d 5 S. 66-71
Begins with 3 mm. mottles.

(67). Sediment 3 d 5 S. 71-74? (3?) (546)

(68). Amygdaloidal melaphyre (31)
Poor amygdaloid 3 d 5 S. 74-87 (571)
Amygdaloid trap 3 d 5 S. 87-105

(69). Ophite, feldspathic (59)
Amygdaloid 3 d 5 S. 105-112 (630)
Red and poor.
Trap 3 d 5 S. 112-164
Feldspathic with doleritic tendency, coarsest at 141-144.

70. Feldspathic melaphyre
Amygdaloid 3 d 5 S. 164-171 (38)
Contact near center? (668)
Trap 3 d 5 S. 171-202

71. Sediment
Chocolate color, dip 80.5°
The frequency of these sediments between the Kearsarge conglomerate and the Wolverine sandstone is noteworthy, though their thickness is usually insignificant.

72. (33)
Amygdaloid Frontenac 3 d 5 S. 202-205
Trap 3 d 5 S. 205-235

73. Ophite (23)
Amygdaloid 3 d 5 S. 235-239 Fissures at 30°.
Trap 3 d 5 S. 239-258
A seamed feldspathic ophite.
Top of Kearsarge lode below base of Kearsarge conglomerate (724)
(35)
(758)

74. Ophite, first of the Kearsarge lode group.
Amygdaloid 3 d 5 S. 258-272 with porphyritic feldspar?

Kearsarge lode.
Trap 3 d 5 S. 272-293
At 273 a seam of calcite and prehnite.
75. Ophite feldspathic (44)
Amygdaloid 3 d 5 S, 293-298
A feldspathic mottling
Trap 3 d 5 S. 298-337

(802)

76. Ophite with the Kearsarge amygdaloid (66)
Amygdaloid 3 d 5 S. 337-340
Coarse porphyritic feldspar crystals in fine ground growing coarser.
Trap 3 d 5 S. 340-403
Coarse ophite, at 375 4 mm., from 396 on, finer.
77. Ophite with a Kearsarge amygdaloid (24) (868)
Amygdaloid 3 d 5 S. 403-408
Trap 3 d 5 S. 408-427
Porphyritic crystals marked to 412.

Total of Kearsarge group with four amygdaloids 169 (982)
The upper two are not so certain; the top of 76 seems to be the main lode.
78. Horizone of Wolverine? Trap
The contact has a highly porphyritic amygdaloid with clasolitic red sandy matter (at 444 feet) which is all there seems to be of the Wolverine sandstone.
427-443
79. Ophite
Amygdaloid 3 d 5 S. 443-448
3 d 5 S. 450-452
Trap 3 d 5 S. 452-453+
Mottling 4 mm. at 508
Fault. From 511 to 523 are a lot of chlorite slips at 22.5° to the hole, and though the grain gets finer about 523 feet no amygdaloid comes in, so I think it is cut out by a fault, very likely one of the nearly vertical ones running across the range.
80. Ophite
Trap 3 d 5 S. 533
After 533 the mottles increase; from 1 mm. to 3 to 4 mm. at 547-557, then finer and full of chlorite slips from 567-575, then coarse 6-7 mm. at 583, then finer to 616.
This seems to be the disturbed representative of the big ophite that generally comes just below the Wolverine.

Cross-Section at Delaware mine. The data for a section here are

(1) The mine map as published by Lawton in the Report of the Commissioner of Mineral Statistics for 1885 near page 218 for instance.

(2) Marvine's statement that the Houghton conglomerate is 1563 (637) feet rom the Allouez.

(3) A sketch of the diamond drill explorations on the Delaware (File 10-12), see Volume V, Part I, page 130, where Rominger gives his idea of things. The dip of the Allouez at the Delaware he calls 23°.

(4) My own notes of Sept. 7, 1905. This is about a half mile east of Manitou 3 section, the bed numbers of which are given.

Fig. 29 The combination record will be somewhat as follows:

20 1. Conglomerate (25)
Allouez
22 2. Ophite Trap (100)
23 3. Amygdaloid (16) (278)
24 Trap
Sometimes doleritic with numerous inclusions as shown in contact
25 dividing in the lower part of the mine map into 123 feet trap 31
26 amygdaloids, 118 trap
4. Ophite (163)
27 Amygdaloid (28)
Trap (135)
31 5. Ophite (76)
Amygdaloid (31)
Trap (45)
Massive, well mottled 617
6. Houghton conglomerate No. 14 (20) (637)

?32 Marvine made this 1563 feet from the Allouez No. 1 horizontally. I find a well-marked upper amygdaloid contact of a flow about 1200 feet from and about 105 below the conglomerate on the old railroad cut, which seems to be the same horizon. Above it some distance is a well-marked ophite. Lawton's mine map doesn't show any amygdaloid close above the Houghton conglomerate. But unless accidentally omitted from the map, its absence in the 8th level would indicate a greater dip and therefore intervening thickness than Marvine assumed, not less than 710 feet, and I think somewhat *more* thickness is really more probable from the apparent thickness in the field of overlying flow, and the correlations elsewhere.

7. Underneath is not well exposed and not explored, 550 feet on and 40 feet lower down, or about (200) to (250)
38 8. The Montreal lode, brecciated with calcite, prehnite and copper, a scoriaceous conglomerate perhaps? (20) (290)
9. Unexplored, must belong in good part anyway to the underlying trap (163) (433)

Delaware drill hole No. 5 is 1025 S. and 42 ft. lower than the base of the Houghton conglomerate, at the level of the Montreal River, and foot of a steep bank.

10.
Trap at top of Hole No. 5 to 45 (37) 470
42. 11. (205) 675
Amygdaloid to 85=40 (37)
Trap to 268=183 (168)
43. 12. (64) (739)
Amygdaloid to 280=12 (11)
Trap to 338=58 (53)
(44) 13. Calumet conglomerate, as generally supposed—347=9 (8) (747)
(45)
14. Trap to bottom 438-½ ft. and at beginning of Holes 2, 3 and 4
(105) (105)

No. 2 is only 40 feet deep vertical and 900 ft. horizontally from No. 5
No. 3 is only 90 feet deep vertical and 910 feet horizontally from No. 5

No. 4 is 232 feet deep vertical and 930 feet horizontally from No. 5 perhaps 5 feet higher. Its record is trap to 38, amygdaloid to 65, trap to 145, amygdaloid to 160, trap to end at 232, when there follows another gap.

(46) 15.				(99)	(204)
	Amygdaloid	65=27	(25)		
	Trap	145=80	(74)		
(47) 16.				(80)	(282)
	Amygdaloid	160=15	(14)		
	Trap	232=72+	(66)		

Next follows a considerable gap No. 1 hole being 2230 feet from 5 and 42 feet above the base. This would make it 1563+1025+2230 feet or 4818 feet from the Allouez. About 220 feet down in it a conglomerate is reported which will then be 4818 feet from and about 320 feet+ below the Allouez. To assume this the same as the Kearsarge at the Central and at the same distance below the Allouez will be to assume a mean dip of 31°, a dip by no means improbable, since in the Central mine section we found steep dips to the south, and we found our correlation for the Houghton and Calumet both falling somewhat short of what we made them at the Central. However, for the present we follow copy, with the comment only that very likely the unexplored thicknesses should be increased some 30%

17. Unexplored+ (290) (572)

Drill hole No. 1 is vertical, 37 feet above No. 4, 1280 feet from it. The record is overburden-32; trap-127; amygdaloid-140; Trap-220; South conglomerate-227; Trap-233-½.

(54) 18.				(87+)	(659)
	Trap 32-127=95				
(5) 19.	Amygdaloid	140=13	(12)		
	Trap	220=80	(73)		
(56) 20.	South conglomerate (the Kearsarge?)-227-7		(6)		750

There is no conglomerate shown at any such position in any other section of which I know, and the inference is strong in my opinion that the dip should be increased somewhat, though there may be indeed be a thinning of the distance between the Calumet and the Kearsarge.

(57) 21. Trap.

§ 6. CENTRAL MINE AND ARNOLD (COPPER FALLS) (FIGS. 30 AND 31.)[1]

Next west of the Manitou is the old Connecticut property, Section 16, T. 58 N., R. 30 West., where the road to Eagle Harbor turns off through a gap which may be a fissure continuing to the Eagle Harbor fissure north of Section 9.

The next mile (Section 17) brings us to the old Waterbury. It is then nearly two miles to veins in Sections 18 (Summit) and 19, which seem to belong to a group of veins in the Arnold and Central mine. (Figs. 30 and 31.) In this belt two important mines have been worked for years, both in fissure veins and by exploration in them, and by combining them (Figs. 30 and 31) we are able to give a pretty complete section from the Lake Shore and the Great Conglomerate very nearly to the Bohemia conglomerate.

[1]Figures 30, 31, 32 and 33 are in envelope.

This section is that given on the old map of Keweenaw Point by Whitney, Hill and Stevens and is compiled from various old mine maps of Emerson and others but down to the Kearsarge conglomerate largely follows the work and notes and sections of Dr. L. L. Hubbard (File 7). Mr. W. W. [illegible] also been of help. The drill co:
by Mr. P. S. Smith
built and adjusted t
the mines had cavec
the Owl Creek vein
of the adit followin
cide. The strike he
of the west side of

The detailed measuren
east side.

Amygdaloid
Amygdaloid Ss. 16781-2
Sandstone Sp. 16783
Amygdaloid Sp. 16784
Trap Sp. 16785
These samples now c
offset which would appe
mentioned amygdaloid
Small sandstone seam S
This may be a clasol
16787. This continues
Amygdaloid Sp. 16784
Sp. 16788
Sandstone Sp. 16789
Amygdaloid or small fl
Sp. 16790
Sandstone and conglor
(Fluccan) Sp. 16791
Amygdaloid Sp. 16792
Trap Sp. 16793
Amygdaloids Sp. 1679
Eagle River Beds
amygdaloid throughou
Trap Sp. 16795
Amygdaloid seam Sp
Probably not to
Trap
Sandstone
This is probably Eagle River Bed No. 17 and is almost the same number of beds from the beginning of the Owl Creek vein adit

[1]Or Collector's Nos. 2 and 2a.

Amygdaloid and trap Sp. 16798	1044–1110	66	(28.5)
Sandstone (Eagle River 20?)	1110–1130	20	(8.6)
Amygdaloid melaphyre and trap (Eagle River 21?) SS. 16799–16800	1130–1270	140	(60.4)
Sandstone (Eagle River 22?)	1270–1302	32	(13.8)
Trap Sp. 16801 Cf. Eagle River 25	1302–1464	162	(69.9)
Sandstone Sp. 16802 Cf. Eagle River 26	1464–1509	45	(19.4)
Amygdaloid and trap Sp. 16803	1509–1595	86	(37.1)
Sandstone Sp. 16804 Cf. Eagle River 28	1505–1647	52	(22.4)
Interval in which beds were not well made out, broken by seam of fluccan flanked by vein matter as shown SS. 16805–7	1647–2267	620	(267.6)

The seam of fluccan is 138 feet from the top of the bed and is about 1½(6)

ASHBED GROUP

Amygdaloid distinctly of porphyrite type SS. 16808–9. Cf. Eagle River 44 to 45	2267–2324	57	(24.5)
More compact SS. 16810-12	2324–2378	24	(23.2)
Amygdaloid SS. 16812-3	2378–2423	45	(19.4)
Closer and more compact part of the same flow. SS. 16814-5 near top and bottom	2423–2590	167	(72.1)
Amygdaloid (really 5 feet wide) Sp. 16815	2590–2598	8 or 5	(2.2)

This is presumably Marvine's heavy bed 62. A little adjustment has been necessary to reconcile the measurements along the vein with the real location of the shaft, mine, etc. (See also section given in the Report of the Commissioner of Mineral Statistics (1888) 1889, p. 87) and has been made in this heavy bed and below. SS.

16816–20	2598–3103	505	(217.9)

Hubbard thought possibly there were two or more beds. The base is a series of slide fluccans which separate it from the Ashbed proper.

Fluccan slides. Cf. Eagle River 63	3103–3123	2½(1 in.)	(17 [7 in.)
Amygdaloid and trap of the Ashbed. Sp. 16822	3124–3149	25	(10.8)
More of the Ashbed Sp. 16823	3149–3183	34	
Porphyrite Sp. 16824 (lower part of the Ashbed)	3183–3338	155	(64)
Trap	3338–3879	(91 feet from N. side of Thomas shaft)	

Center of the Thomas shaft was at 3783 and at 3838 was a cistern beyond which

it was impossible to examine. The rest of the measurements are compiled from old mine maps. Hubbard's first estimates would make this trap 450+91.

i. e.		541	(228)
Amygdaloid	3879–3889	10	(4.3)
Trap	3889–4024	135	(58.3)
Amygdaloid	4024–4034	10	(4.3)
Trap	4034–4094	60	(25.8)
Amygdaloid	4094–4104	10	(4.3)
Trap	4104–4134 and 4279	30+145	(12.9)+(62.6)
Sandstone	4279–4284	5	(2.2)

This is evidently the first sandstone south of the Ashbed, corresponding to the Eagle River 83 to 85 perhaps

Trap	4284–4524	240	(110.1)
Sandstone	4524–4534	10	(4.3)

This apparently corresponds to Eagle River Bed 85 and perhaps to the Pewabic West conglomerate, Marvine's No. 16 at Portage Lake and from here on the section must be patched a little, the position of the beds in Fig. 30 being taken from Manitou 3 section. It is said, however, that the unexplored part of the adit was continued something like 3500 feet beyond the Ashbed and reached the Greenstone.

Capt. Clark of the Arnold reports that "a dike 18 inches to 2 feet wide was met in the 9th level in the 'Pewabic belt' running a little north of east and south of west, nearly vertical, which threw the formation down on the north about 22 feet vertically."

"The Owl Creek vein was explored deeper north of or above the Ashbed than below where it was poorer. There are three veins west and two east of the Owl Creek vein that fault the Ashbed alternately in opposite directions," and three on the east that do not fault it. "The main vein has the east side 32 paces or so north." From notes by L. E. Emerson on an old map we have the following data, besides the distances to various contacts used in the section.

Ninth level adit measuring north from north wall of Spencer shaft at Ashbed.

At 1393 Feldspathic copper bearing belt.

At 2475, 2525, 2550, 2603, 2674, 2655, 2683, 2743, 2797, 2840 ("Silver bearing belt") contacts being beds called amygdaloids, bearing analcite, datolite, prehnite and calcite. Also at 320 to 350 feet south of Thomas shaft, mottled rock.

In Fig. 30 I have given numbers corresponding to belts in the Eagle River section down to Eagle River belt 87. Then for a part of the adit south of the Thomas shaft entirely unexplored and for which no data at all can be obtained from mine maps, I have

taken the liberty of patching in the belts from Manitou 3 (Fig. 27) as the Eagle River section is incomplete just here. The Eagle River section makes the interval from No. 85 to the Greenstone only 353 feet against 506 in Manitou 3 which is somewhat disturbed. Quite possibly then the section to the Greenstone is thinner than shown, and the Greenstone correspondingly thick. The section as drawn makes it 1,330 feet. Stockly reports mottles 3 inches across. I have seen them over two. This at a rate of increase of .000375 would mean 1,333 feet. It is safe, certainly, to allow over 1,000 feet above the Allouez with no amygdaloids.

South from the Greenstone to the Kearsarge conglomerate the section given in Figure 31 was shown in the works of the Central Mine on the vein of that name. The section is partly given in detail in Volume I, Part II, Chapter VI. It can be completed from later mine maps and investigations by Dr. Hubbard[1] down to the Kearsarge conglomerate.

At this point there is a slide displacing the vein 284 feet and apparently the country rock "above the conglomerate between the east and west veins has moved to the north, thus producing along the west vein the relations of a reverse fault and along the east vein those of a normal fault," as very carefully studied by Hubbard and shown in Plates I, II and III of the article referred to, which as they were prepared for the Michigan Geological Survey are herewith reproduced as Figures 31 and 32, the west vein below the Kearsarge conglomerate being the displaced east vein above it.

The detailed section follows: The core boxes were scattered and had to be studied at different times, but were among those most carefully examined. P. S. Smith examined 1 and 2. T. Dengler furnished the locations. When the drilling was done the increased dip to the south was not fully appreciated. Some of the holes, also, are on one side of the fissure, some on the other. Nos. 1 and 8 though nearly in line of strike do not at all correspond with each other. Thus in the section (Fig. 33) I have not tried to give 1 and 2 in their geographic position but rather in their geologic which as will be seen means a vertical displacement of some 680 feet.

If we may judge by the Frontenac section this fails by only about 700 feet to reach the Bohemia conglomerate. This agrees with the fact that it covers the ground down to the south line of Section 36, T. 58 N., R. 31 W. The Praysville porphyry and other exposures help us to locate and identify the Bohemia horizon as crossing the south line of Section 36.

[1]Lake Superior Mining Institute, Vol. III., p. 74.

Abstract of Central mine Cross-section.

Belt			
No. 0.	Beginning at base of Allouez conglomerate, which is about (10) feet thick.		
13.	Melaphyres ophites—none over (75) feet thick. Dip about 24°		
14.	*Houghton* conglomerate felsitic (10) below the base of the Allouez (640) to (685)		
15.	Of ash bed type (61)		(730)
	Melaphyres up to 96 feet thick (probably including ophites)		
26.	*Calumet* conglomerate (15), base below Allouez base		(1500)
	Ophites mainly—some over 100 feet.		
31.	Ophite (108) base below Calumet 384 feet.		
39.	Ophite (10 mm. x 4 mm. augite) (194) base below Calumet		1020.
41.	Fault fluccan over Kearsarge base below Calumet		1128
	below Allouez		(2628)
	Dip about 27° according to Hubbard below Allouez		(2599)
42.	*Kearsarge conglomerate* (62),—from Houghton cg. (2021)		
	below Allouez		(2690)
43, 44, 45.	(end of mine section) below Kearsarge (233)		
	below Allouez		(2923)
(46 bis)	Cend. 2 base of first flow in Cend. 2 at 80		(3114)
50.	Red shaly sediment, below base of Kearsarge (469)		
	below Allouez		(3159)
53.	Kearsarge hanging ophite (73) below base of Kearsarge		(587)
	below Allouez		(3277)
54, 55.	(90) and (75) Repetition or two flows of K. F. Kearsarge amygdaloid		
56.	*Wolverine sandstone*, below Kearsarge conglomerate (752)—		
	below Allouez		(3442)
	below Wolverine sandstone		(281)
58.	Ophite big 2.442-498=8.42-314 (250)		
59.	Sc. Am. 60 choc. ss. (see Franklin J. 3.535)	(311)	(3752)
61–71	Small beds of feldspathic ophite type	(485)	
72.	Ophite (122)		
73–75.	Small beds 5.88=8.722 76 sediment 5.98-100	(641)	(4083)
77–79.	78 inclusion bed feldspathic doleritic datolite	(149)	
	79 feldspathic ophite (179)	(999)	
81.	Sandstone (7) 5.585-593	(1042)	(4484)
82–87.	Small feldspathic beds 5.807=3.182	(1216)	
88–93.	" " "	(1372)	
96.	Conglomerate 3.608-612=4.67-68	(1577)	(5019)
97–101.	Glomeroporphyrites, red, gl. am. light fels. tr. chloritic, faint, or no mottles 4.675=6.39	(2072)	
102–107.	Glomeroporphyrites, heavier and more ophitic at base 107=6.352-544=6 A. 290-414	(2482)	
108–112.	Glomeroporphyrites, heavier and more ophitic at base, 112=6.650-801=7.37-257 (205)?	(2772)	
113.	Ophite (203)		

114–115.	Small flows glomeroporphyrite?	(2975)	
116.	Doleritic ophite.	(3284)	(6726)
	The dip from Hole 2 to 7 is not far from 35 degrees.		

This Central mine Cross-Section is in continuation of the section in Volume I, Part I, Chapter VI, of the Reports of the Geological Survey of Michigan, adding the results of the deeper mining, especially as given in the reports of the company, Dr. L. L. Hubbard's paper in the Transactions of the Lake Superior Mining Institute 1895, pages 74-83, and recent drilling. The whole figure (33) makes a fairly complete section from the Allouez conglomerate No. 15 nearly down to the horizon of Conglomerate No. 8. The upper belts are abstracted merely, those now published for the first time are given more fully. Mr. Philip S. Smith examined very carefully drill hole 1.

	Allouez conglomerate or Slide (No. 15)		10	Running Totals.
1.	Melaphyre			(36)
2.			(40)	
	Amygdaloid	(14)		
	Melaphyre	(26)		(76)
3.			(35)	
	Amygdaloid	(14)		
	Melaphyre	(21)		(111)
4.			(101)	
	Amygdaloid	(14)		
	Melaphyre C. 1[1] Trap			(212)
5.			(87)	
	Amygdaloid C 2	(18)		
	Chocolate brown, prehnitic, with copper[2] gradual transition to C. 3; the Medora lode?			
	Melaphyre C. 3	(45)		(275)
6.				
	Amygdaloid C. 4	(16)		
	Brown matrix, with prehnite, copper, calcite amygdules, laumontite veins, feldspar vugs.			
	Melaphyre C. 5	(55)		(346)
7.				(346)
	Amygdaloid C. 6	(15)		
	Brown matrix with delessite and calcite amygdules			
	Melaphyre C. 7	(40)		(401)
8.				
	Amygdaloid C. 10 and C. 11	(15)		
	Brown matrix.			
	Melaphyre C. 12 and C. 13	(60)		
	Very thick and uniform just like C. 5			
9.				(476)
	Amygdaloid C. 14	(15)		
	Brown matrix, with cupriferous prehnitic amygdules			
	Melaphyre C. 15	(37)		(528)
10.				
	Amygdaloid C. 16	(17)		

[1]Pumpelly's original number. See Vol. I., Pt. II.

[2]It must not be forgotten that samples are taken near the Central vein. Pumpelly calls only the trap or compact part melaphyre. In modern use of the term it is applicable also to the amygdaloid top.

Brown, very hard compact, with amygdules of prehnite, and calcite with green earth

Melaphyre C. 17 (45) (590)

11.

Amygdaloid C. 18 (22)

Melaphyre C. 19 (5) (617)

12.

Amygdaloid C. 20 (5)

Brown with amygdules of epidote, or delessite and red feldspar

Melaphyre C. 21 (5) (627)

13.

All the melaphyres so far said to be alike, like C. 5

Amygdaloid? C. 22, 23, 24. (12)

Melaphyre C. 25 (10) (649)

14. *Houghton conglomerate*

Porphyry conglomerate with epidote cement and disseminated copper in both pebbles and cement C. 26 to 34 (10) (659)

This is the Houghton conglomerate (14) and the vein in this conglomerate carries large crystals of calcite. Scaling the distance from the base of 15 to the base of 14, on the mine map it varies from (640′) to (685′). Marvine makes it 1685′ horizontal or (665) feet, implying a dip of 23°.

15.

Amygdaloid C. 35, 36 (16) (61) (720)

Said to be of Ashbed type, amygdules almost wholly calcite.

Melaphyre C. 37, 38, 39 (45)

Said to be fine grained, but the lower part is minutely mottled and hence an ophite. Altered olivine "copper colored micaceous"; delessite; "soft white" altered feldspar are mentioned.

16. (83)

Amygdaloid C. 40 (15) (803)

Brown with amygdules of green earth, green earth and calcite, and feldspar with copper

Melaphyre C. 42 (68)

Very fine grained with even fracture, containing small crystals of plagioclase and altered olivine.

By scaling from the mine map it appears that in continuous cross-section this should be a total of (830)

17. (54)

Amygdaloid C. 43 (20) (900)

Green and brown with amygdules of green earth, calcite, copper, analcite.

Melaphyre C. 44, 45, 47, 48. (34)

Harder than C. 5, with perfect conchoidal fracture.

18. (59) (962)

Amygdaloid C. 49 (16)

Brown, with prehnite and calcite and chlorite amygdules.

Amygdaloidal melaphyre C. 51

Melaphyre C. 52 (43)

Like C. 5.

19. (96) (1058)

Amygdaloid C. 53 (28)

Soft brown with calcite and altered prehnite

Melaphyre (68)

20.			(70)	(1128)
	Amygdaloid	(25)		
	Melaphyre	(45)		
21.			(122)	(1250)
	Amygdaloid C. 54	(13)		
	Purple-brown amygdaloid with prehnite			
	Melaphyre C. 56	(15)		
	Hard, fine grained, with altered olivine.			
	Amygdaloid C. 57	(10)		
	"Probably not a persistent bed", brown, with isolated amygdules of prehnite and chlorite.			
	Amygdaloidal Melaphyre C. 58	(16)	(50)?	
	Melaphyre C. 59 and 60 (68)			
	Same type as C. 5			
22.				(1289)
	Amygdaloid C. 61	(9)		
	Soft brown with prehnite, analcite and copper			
	Melaphyre C. 62	(30)		
			By direct scaling	(1300)
23.			(39+?)	(1328+?)
	Amygdaloid	(9)		
	Melaphyre C. 63	(30)+		

From Belt 19 there is a short interval that can be filled only by a mine map (reproduced reduced in Lawton's report of the Commissioner of Mineral Statistics for 1899) which does not, however, agree at all closely with Marvine and Pumpelly's map, Plate 23 of Volume I. There may be 30 feet discrepancy. Yet all maps agree in bringing the next conglomerate, the Calumet & Hecla, at the intersection of No. 2 shaft and the 16th level, and the mine map gives two amygdaloids between that and the 13th level. We reckon accordingly.

24.			(96)	(1424)
	Amygdaloid	(16)		
	Melaphyre	(80)		
	The second belt above the Calumet is often quite a thick one. Cf. Mandan 1. 668-835.			
25.				
	Amygdaloid	(15)		(1493)
	Melaphyre above the Calumet .	(54)		
	Hubbard gives this in figures subject to revision as (1474) feet.			
26.				
	Conglomerate No. 13. The Calumet		(15)	(1500)

On the 13th level the base of this appears to be 546 feet south of No. 2 shaft. On the 21st level an inclined shaft which follows it down from the 20th level is 855 feet north of the shaft which is 12 feet wide. The apparent dip would be 23°¾. According to Capt. M. Trethewey they drifted at the 190 fathom level to the east 1800 feet to the northwestern vein. The lode was rich for only 30 or 40 feet.

From the base of the Houghton to the base of the Calumet is (831)

Below this conglomerate the old mine map would give us Trap (62), Amygdaloid (22); Trap (100) to (184); Amygdaloid (14), Trap (120) to (418); Amygdaloid (10) feet, but from this point on the mine was

carefully examined and mapped by and under L. L. Hubbard, whose remarks in the mine are put in quotations.

Running totals from base of Calumet

27.
Amygdaloid (3) Sp. 16774
Trap (68) " 16773 (71)

"At about 31 to 34 paces from" the foot of this trap "there is a slide in the east wall of" the 21st "level running from N. W. to S. E. and nearly parallel with a vertical through this level; another like it occurs a few paces farther north. The conglomerate,—or rather the top of the amygdaloid under it, is about seven feet or more higher on the west side. We climbed up above the level just under the old inclined shaft. On the east side the vein wall is grooved and polished for 20 feet or more, the grooves having a northerly dip about 5°. This agrees with two other occurrences of the same kind that I have noticed previously in this mine".

From 685 to 858 N. on the 21st level.

28. Ophite. (98) (169)
Amygdaloid (16) Sp. 16772
Trap (82) Sp. 16771 just beneath the amygdaloid 16772
Sp. 16770 just above the amygdaloid 16769
16770 is finer grained than 16771
From 444 to 665 N. on the 21st level

It is possible that 28 with this makes up the single large flow that often occurs close under the Calumet conglomerate.

29. Ophite. (27) (196)
Amygdaloid Sp. 16769 (1)
Amygdaloidal melaphyre Sp. 16768 (9 paces) (12) (10)
Trap? Sp. 16767 (11) paces
From 377 to 444 N. on 21st level.

30. Ophite. (80) (276)
Amygdaloid Sp. 16766 (5)
Trap Sp. 16765, 16764 (70 paces) (75)
16765 is 1 to 2 mm. mottled?, 16764 is finer
From 182 N. to 377 N. on 21st level.

31. Ophite. (108) (384)
Amygdaloid Sp. 16763, 16762 (7-½)
Trap 16761, 16760 (95)
From 182′ north to 84′ south on the 21st level = 264′ x sin 24°

Total on 21st level from the base of the Calumet conglomerate 26. 858+84=942 x sin 24°=384. A dip of 27° would imply a thickness of 440 feet, and the mine map evidently assumes a steeper dip than 24°. This may be the hanging of the Osceola amygdaloid. It should be between this and flow 35.

32. (109) (492)
Amygdaloid Sp. 16759 at the end of 21st level (9)?
Trap ? (possibly two or more belts) (99)
From 84 S. in 21st level to 25′+N. in 23rd level

33. 59 (551)

Amygdaloid Sp. 16758 (7)

A brown amygdaloid, brecciated with chloritic amygdules

Trap From 25 N. in 23rd level to 103 S. (52)

34. (42) (593)

Amygdaloid (20)

from 103 to 153 S. of 23rd level

Trap (21)

from 153-205 S. in 23rd level

About here should be the horizon of the Osceola amygdaloid, above or below Belt 33.

35. Ophite. (141 say)

Amygdaloid

From 205-215 S. in 23rd level (5)

Trap Sp. 16750, 16751 (63) + (35?)=98 + ? (734)

To the caved-in end of the 23rd level South, 360′+ at which point the rock is still a well-marked ophite, Sp. 16750, and the mottling is 2 or 3 mm. across, so that the belt must be close to 100 feet thick, for this grain if below the center would be perhaps 35′ from the bottom.

Now the top of the northern-most amygdaloid in the 31st level at 1215, is by scaling at a dip of 24° just 100 feet below the top of this Belt 35. Above it to 1375 is trap. Ss. 16682 and 16681.

Sp. 16681 is fine grained massive ophite. Sp. 16682 is coarser than Sp. 16750, the mottling being estimated as 4 mm. across by the eye. This is about what might be expected over 40 feet above the bottom of the flow, and points to a flow over 80 feet thick. The Kearsarge conglomerate directly below dips 20°48′. The distance between the N. end of the 31st level and the S. end of the 23rd being 1800 feet more or less, a variation of a degree in the dip assumed will mean about 30 feet in the thickness of this belt. So, for instance, if we prolong the lower beds up straight we get a thickness of 220 feet as a maximum, and if we prolong the lower beds down we get 30 feet as a minimum. In such a case the grain indications are of much value. A thickness of 141 feet which we choose means a mean dip of slightly less than 23° and is probably nearer the truth for this bed at this depth. We take 141 feet, in order to make the totals by beds agree with the scaled distance from the Kearsarge to the Calumet at a dip of 24° from 858′ N. in the 21st level to 307′ N. in the 32nd.

36. (18)

Amygdaloid Sp. 16680 (3)

From 1215 to 1207 in the 31st level.

Trap 1170-1207 (15) (752)

37. Ophite. (48) (800)

Amygdaloid (1)

From 1167-1170 in the 31st level N.

Trap Sp. 16679

1055-1167 (47)

Sample of trap taken near lower contact, "the farther north it is the more mottled".

38. Ophite. (26) (800)

Amygdaloid Sp. 16678 (6)

Sample of amygdaloid near upper contact, 1055-1039 in 31st level N.

Trap Sp. 16677 (20) (826)

1039-987 in 31st level N.

39. Ophite. (194) (1020)

Amygdaloid Sp. 16676 (18)

Sample from near top 987-940

Trap Sp. 16675 (16674 bunch of Am.) 16673, 16672, 16671, (176)

Of the samples from this massive trap Sp. 16671 is the coarsest, the average diameter being about 6 mm. I think they tend to a prismatic form 10 mm. long x 4 across. It is supposed to be only 118 (48) feet below the top. Sp. 16674 is seamed and pseudoamygdaloid. 16673 is very full of irregular druses lined with epidote crystals. It may be doleritic but seems more like a vein. Ss. 16673 and 2 represent "seams of coarse rock" "the upper 1 to 2 feet wide, the lower 6 in." The two seams on the east side tend to form a lens although they do not meet in the level. On the east side they are 6 feet apart in the widest part, horizontally. The two thicker seams, 4 feet above the floor of the level are 32 feet apart horizontally, the west side being the farthest north. This, with the belt below, is perhaps the rather persistent heavy belt just above the Kearsarge conglomerate which often lies just between two heavy ophites.

40. Ophite. (103)

Amygdaloid Sp. 16670 (5)

493-505 in 31st level N.

Trap (mottled) Sp. 16669, 16668, 16667 (98) (1125)

Sp. 16669 is 93 feet from the conglomerate (38).

The mottling appears to be 3 to 4 mm.

The contact of the trap and underlying vein is in the roof at the beginning of the 31st level N., and the belt runs say from 230-493 in 31st level N. The amygdaloid at the top while fine grained does not seem to be a very pronounced belt.

41.

Fault fluccan just overlying Kearsarge conglomerate (3) (1128)

Sp. 16664 (Hubbard made the distance from the Calumet 1125′ and the total distance from the Allouez 1474 + 1125 = 2599 feet)

Sp. 16697, etc.

42. Kearsarge conglomerate (62)

From the Calumet conglomerate (1190)

Hubbard[1] discusses the identity of the "Kingston" conglomerate with the Kearsarge. This outcrop is really 500 feet (not paces, Irving) south of the quarter post of Section 33, T. 58 N., R. 31 W., and not the center as given by Marvin and Irving and followed by Hubbard, although Irving gives the distance from the Greenstone 4650 feet. Bringing this half a mile north, if we assume it to be the Kearsarge as I think we must, we must increase the dip accordingly to about 35°. There seems to be a number of misprints about this exposure.

As to the slide in the Central, see Hubbard in Lake Superior Mining Institute, 1895, as *corrected* in Volume VI, Part II, page 87. See also pages 85 to 96.

[1]Vol. VI., Pt. II., p. 85.

The Kearsarge conglomerate varies greatly in thickness and is very nearly wiped out by the slide above.

Capt. Tretheway says that the water above it was so salt that it caused itching and sores.

From the base of the Houghton (2021)
" " " " " Allouez (2690)

The 30th level continues the section below the Kearsarge conglomerate which in that level appears to be only 23 feet thick.

43. (136) (136)

Amygdaloid Sp. 16695
From 66.3 to 76 in the 30th level S. (4)
Trap Sp. 16698 (132)
From 76-402 in the 30th level S.
This belt is generally thicker.

44. (82) (218)

Amygdaloid Sp. 16699 (10)
From 402-427 in the 30th level S. grey-green with epidote, quartz, calcite.
Trap Sp. 16700, 16702
From 427-603 in the 30th level S. (72)
The contact between 41 and 42 occurs on both sides of the level and the west side is thrown farther forward, northward.

45.

Amygdaloid 16703, 16701 (8) (233)
From 603-610 in the 30th level S.
Trap 16702 (7) (15)
From 610-640 in the 30th level S.
Below the base of the Allouez conglomerate. (2923)

46. Ophite. (191) (3114)

Amygdaloid Sp. 16704 (20)
From 640-684 in the 30th level S.
Trap (platy) Sp. 16705
From 684-687 end of level which is 252 feet below the Kearsarge or about 2923 feet below the Allouez?

The section from this point is continued by drill holes (1) and (2), the cores examined by Lane, and that of No. 1 by P. S. Smith. Evidently in planning the holes the dip was assumed to continue about 24° as in the mine. In this case drill hole No. 2, the one farthest north, would begin only [6472.+ (184-61) x cot 24°] sin 24° = 2740 feet below the Allouez, that is to say, almost immediately beneath the Kearsarge conglomerate and lapping the belts of the 31st level S. But this dip is too small for:

1. Drill hole 2 and the belts of the 31st level South do not harmonize.

2. The distance from the Kearsarge conglomerate, and what we identify as the Kearsarge amygdaloid would be altogether too small (3073-2690 = 383 instead of 800 or 900 around Calumet or 500 or 600 farther out on the point).

3. Drill hole 2 should lap the top of drill hole 1 at a depth (840+ (61-46) cot 24°) sin 24° = 355 feet, and the belt 2.333-408 is a very characteristic one, the Kearsarge foot. This does certainly not appear in drill hole 1, which does not appear to lap drill hole 2 more than a trifle at most.

4. The holes put down at 66° do not appear to strike the sediments *exactly* at the right angles to the bedding, and the dips measured in vertical drill holes seem to be more. For instance the dip of the d 5 sandstone at 585 seems to be about $34°\frac{2}{3}$.

The outcrop of the so-called Kingston conglomerate is wrongly given by Marvine, and following him Irving and Hubbard as Hubbard afterward found being half a mile further north, 500 paces S. of the N. quarter post (instead of center) of Sec. 33, T. 58 N., R. 31 W. This reduces the horizontal distance from the Greenstone and invalidates Hubbard's arguments as to dips in his Lake Superior Mining Institute paper 1895, p. 86.

6. In the Central mine itself we find the dip of the Kearsarge increasing toward the surface up to 27°.

7. All the correlations of the drill holes farther S. point to a dip in them not far from 35°.

The seven reasons given above are conclusive it seems to me as to the extreme probability that the section covered by the diamond drill cores dips considerably more than 24°. There is of course especially near a line of disturbance like the Central vein much possibility of errors due to unallowed faults and consequent throws.

Referring to the objections above listed:

Objection 1. will be obviated by any dip over 26°.
" 2. " " " " a dip of about 27°.
" 3. " " " " any dip over 35°.
" 4. " " " " dips from 30° to 40° apparently.
" 5. " " " " a steeper dip depending on the exact location and elevation of the outcrop in question, relative to the Greenstone opposite.
" 6. Will be obviated by a dip of 27° or a little more.
" 7. Will be obviated by a dip about half way between 24° and 35°.

On the whole it seems to me most fair in continuing the section to assume an average dip for the whole width from the Allouez thus far of 27°. This will satisfy objections 1, 2 and 6, and allow the indications of steeper dips in the drill holes to balance the flatter dips of the upper part of the mine.

In such case the top of drill hole No. 2 will be about 3064 feet below the Allouez conglomerate if the strike be N. 72° E., or if the strike is, as is most likely N. 80° E., 3034 ft. An average dip of 29° to 30° would make the distance 3300 feet or so. This would make the bottom of the first flow at 80 feet, 3114 feet below the Allouez conglomerate. If we suppose that the bottom of Belt 43 is the top of Hole 2 it would make it (3114-2923) = (191) feet thick.

Now the grain in drill hole 2 seems to decrease steadily from the first samples with a grain of 5 mm. so that the belt is not less than (81) feet thick, and there is nothing inconsistent in supposing it to be the lowest belt exposed in the mine. It is possible it represents the base of the large ophite under the Kearsarge conglomerate 250-300 feet thick (at the Mandan 268).

(46 bis) (continued) Ophite to Cend. 2.80
At 39, 48, 67, 71 feet, 5, 2-3, 2, and 1 mm. mottles.
0-39 is over burden of sand?
Base below base of Allouez conglomerate (3114)

47. Ophite. (16)
Amygdaloid d 2.80-86 (6)
With a little copper.
Trap d 2.86-96 (10)
Mottles up to 2 mm.

48. Ophite. (10)
Amygdaloid d 2.96-97 (1)
Trap d 2.97-106 (9)

49. Ophite. (16-½)
Amygdaloid d 2.106-115 (9)
Trap d 2.115-122′4. (7½)

50. Sediment d 2.122′4″-124′9″. (2-½)
Red shaly sediment with amygdaloid scoria. The bedding is not over 5° to 10° from being at right angles to the hole.
Base below base of the Kearsarge conglomerate (469)
" " " " " Allouez " (3159)
Cf. F J d 4,463, and M 7 d 4 S. 336′ which is about 1625′ below the C. & H., and 470 below the top (?) of the Kearsarge, also R. 1, 4, 535 etc. Between this and the Wolverine there is generally a distinct tendency to be feldspathic.

51. (14)
Amygdaloid d 2.124′9″-129 (4)
Trap d 2.129-139 (10) (483)

52 Ophite (31)
Amygdaloid d 2.139-146 (7)
Coarse, feldspathic, with forms suggestive of porphyritic crystals, chloritic
Trap d 2.146-170 (24) (514)
The bottom contact makes an angle of 7:2 with the drill core. The dip inferred would be 40°.

53. Feldspathic ophite. (73)
Amygdaloid d 2.170-179 (9)
Rather coarse and feldspathic with rare amygdules at 179; copper at 202. This has rather the structure of the Kearsarge foot. Cend. 2179 = F. J. 4.608?
Trap d 2.179-243 (64)
At 204′6″ though coarse only *faintly* ophitic. The mottling at 222 is uncertain, appearing to be about 5 mm. (much too coarse for the ordinary augite mottles. This mottling continued to 237).
Base below base of the Kearsarge conglomerate (587)
" " " " " Allouez " (3277)

54. Kearsarge (Foot)? a porphyritic ophite? (90)
Amygdaloid d 2. 243-247 a red amygdaloid with red feldspar phenocrysts and small red amygdules.
d 2. 247-251 similar with red bordered green centered amygdules
d 2. 253-257 hard fine grained amygdaloid

d 2. 257-259 coarser seamed?, with copper
d 2. 259-264 not very amygdaloid but very fine grained and porphyritic and brecciated.
d 2. 264-273 amygdaloid but coarser with much sludge and probably in or crossing a fissure.
d 2. 273-276 Heavily veined with calcite (33)
Trap d 2. 276-287 Slightly amygdaloid, but ophitic, 2 mm. mottling at 297, 3 mm. mottling at 308 (a coarse ophite), and still markedly ophitic at 324, but growing finer. Then at 333+ very chloritic and full of slickensides, probably crossing a fault, not the bottom of the bed. But we have a return of amygdaloid (57) (677)

55. Kearsarge (a porphyritic) ophite. (75) (752)

Amygdaloid d 2.333-338. Well-marked with red amygdules and phenocrysts or porphyritic crystals and groups of plagioclase up to 20 mm. long (5)=?

Trap 338-408 (70)

Below 338 the regular Kearsarge trap comes in a relatively undisturbed state. At 348 mottlings 2 mm., phenocryst 6 mm., at 361 mottlings 2 mm., at 374 it appears finer grained, more feldspathic, faintly amygdaloid at 376-381.5, there is a little copper; at 396-400 the mottling is still about 2 mm.

It seems probable that here there is some disturbance, especially at 333 and consequent repetition. Pretty surely 333-408 does not show the top of the bed, nor does 243-333 show the bottom. There may here be two or three or more flows with marked phenocrysts, instead of the one often found farther south, or Belt 55 may be merely the lower part of 54 repeated. This I am really inclined to think, yet it is hardly safe as yet to strike out a number and the thickness corresponding from the column.

56. Sediment. Red sandstone or shale the Wolverine No. 9? (0)

There is a little sandstone at 408 and again a little below 411, associated with a fine grained well-marked bottom contact.

Base below base of Kearsarge conglomerate (752) ft.
" " " " Allouez " (3442) "

Cf. (853) from Kearsarge to Wolverine at Wolverine, (893) at the Arcadian, 689-750 at the Mandan, 825 at M 7 S.

57. Ophite.

Amygdaloid d 2. 411-415 (4)

Poor.

Trap d 2. 415-442 (27) (31)

Base below base of the Wolverine sandstone (31)

At 418 and 427 mottles 1-2 mm. and 2 mm.

Cf. at the Arcadian d 2.178-262

58. Ophite. (250) (281)

Amygdaloid d 2. 442-445 (3)

Amygdaloid ill-defined and brecciated with epidote seams.

Trap d 2. -498+=(43)?

At 457 the mottles are 2 mm. across

This we assume equals 8.42-314 letting 8.42=2.457, because

elsewhere we find a very heavy trap immediately under the Wolverine sandstone, e. g. Mandan 6.239-649 M. 7.5. S 58-333. Cf. Arc. Belt 68, 20.315-464.

Central mine, drill hole 1. 562 feet deep, dip 66° to S. 18° E., elevation (about 1291 A. T.) 46 feet above datum. This is probably so nearly at right angles to the beds that no correction for thickness is necessary. 840 feet horizontally below drill hole 2.

1. Ophite (overburden?) to 27 (27)
2. Breccia d 1. 27 to 28 (1)
3. Melaphyre d 1. 28 to 43 (15)
4. Amygdaloid d 1. (43-51) and
   Ophite d 1. -67+? (24)
   The amygdaloids above and below are scoriaceous; at 62 feet there is a 1 to 2 mm. mottling.
5. Confused scoriaceous conglomerate and green epidotic sandstone with sludge. (d 1. 68-120)? (52)
   At 88 feet there is a sludge of calcite and epidote; at 93 fine grained trap; at 97 epidote and copper; at 108-112 a fine grained white banded sandstone which dips against the drill cores 2:8 so that the dip would appear to be (90-66°+14°) 38°? To 120 feet remains fine grained sandstone, and it occurs frequently in the next few feet below. I take this general horizon to be not far from that of the Wolverine sandstone No. 9.
6. Trap, boulder or wedge of ophite? d 1. 120-126 (6)
7. Sandstone and conglomerate. d 1. 126-130+ (4+)
   126-130 sandstone, the conglomerates with red scoria and green sediment; at 130 a fine grained ophite; at 138 a fine grained sediment again; at 144 to 146 a fine grained green sandstone full of very fine copper; at 146-151 a fine grained trap; at 151-153 a fine grained green sediment with banding at 6:8 (i. e. 90° − 37°) with the hole; at 153 to 158 trap again; 158-160 green sediment; to 162 green sediment and amygdaloid; to 166 trap and from here on it seems to be a normal ophite. The above may be more or less of fissure filling, the division is quite uncertain and resembles d 8. 314 to 350.
8. Ophite, etc. d 1. 130-158 (28)
9. Ophite with green sediment and amygdaloid top. Central d 1. 158-259 (101)
   It is suggestive that something is wrong that the mottling is not as coarse as it should be for a bed this thick. The hole may have gone astray. We have at
   171, 178, 188, 190 to 208 coarsest with mottles of
   1-2, 2, 2 mm.
   If the dip of the beds were steeper, say 60° to 70°, this would be quite normal.
   From 244-246 brecciated epidotic.
10. Ophite, with a top of scoria and sediment.
    d 1. 259-264 scoriaceous amygdaloid and conglomerate
    d 1. 264-268 trap
    d 1. 268-272 scoriaceous with red sediment

d 1. 272-282 amygdaloid
d 1. 283-285 sediment
d 1. 286-291 ophite 351 (92)
11. Sediment d 1. 354-357 (3)
12. Melaphyre d 1. 357-363 (6)
13. Ophite. Amygdaloid to 367
Trap to 371
Fissured somewhat amygdaloid to 385
Ophite growing finer to 314 (51)
14. Amygdaloidal melaphyre, d 1. 414-416 marked amygdaloid
-421 fine grained trap (7)
15. Ophite d 1. 421-456
A red amygdaloid with prehnite seams to 426, then more compact and at 445 faintly ophitic.
16. Ophite d 1. 456-500 (44)
Amygdaloid d 1. 456-459
459-461 Epidotic seam, more or less amygdaloidal to 446, then ophitic to 500 feet
17. Ophite. Inclusion bed? d 1. 500-550 (50)
d 1. 500-505 amygdaloid, and at 506, 511, and 515 to 522 more amygdaloid streaks, and at 529 a curious amygdaloid seam or bomb.
18. Ophite, beginning with scoriaceous amygdaloid.
d 1. 550-555 (3+)

The fuller descriptions of P. S. Smith follow. Most of the descriptions are brief and it may be well to give detailed descriptions of this one set,

Examination of Central mine drill cores, Hole No. 1, by Phillip S. Smith.[1]

Label on Box, Hole No. 1, 0 to 112 feet. Stencil number No. 1.

The rock saved by the drill is a dark brown, moderately coarse grained trap showing some alteration and decomposition of the various constituents. Chlorite in small quantity is present. Following this is a gravelly sand which looks as though it might have been produced by rock very similar to the above, the larger fragments showing the same brownish, red trap characters. Calcite is seen also to be present in this sand. The lower end of this portion from the surface to 27 feet is represented by a particularly brecciated sort of rock, in which there is a considerable amount of epidote. The trap fragments which constitute part of this breccia are of a reddish color and portions of the trap show a considerable number of small, rather regular amygdules. These trap and amygdaloid fragments are seen to be abundant in a matrix of a lighter, reddish color which on fresh fracture appears as a lightish gray colored rock. The trap fragments are irregular in outline and the corners are sharp and angular.

27 to 28. The rock consists of a breccia the same as that previously described with the exception that the amygdaloidal fragments are much more scarce. The trap fragments are extremely angular and are surrounded by the same bluish gray matrix. This matrix in one instance has apparently split one of the trap pebbles in two and appears like a little sandstone vein in the drill core. Following this

[1]The terms horizontal and vertical as used of veins in this paper refer to the attitude with respect to the core. Thus a horizontal vein is understood to mean a vein parallel with the shorter axis of the core, thus running at right angles to the direction of the drill hole and parallel with the formation. By vertical vein we mean a vein cutting the drill core parallel with its longest axis, thus being parallel with the plane of the drill hole.

breccia is a dark, reddish-brown trap with ball-like segregations of chlorite. These balls of chlorite separate out from the ground mass on fracturing. Cross section of one of these chlorite aggregations shows in the center laumontite surrounded by chlorite.

28 to 29. This is the same sort of rock as the preceding, with the exception that the bunches of chlorite are less evenly dispersed throughout the mass and at the base the rock becomes more solid trap and free from this pseudoamygdaloidal character.

29 to 31. Practically the same kind of rock as the latter with the bunches of chlorite sparingly scattered throughout.

31. Three veins of a chloritic mineral intersect at varying angles from nearly horizontal to nearly vertical. The rock has practically the same character as the preceding with the bunches of chlorite becoming less frequent.

31 to 33. Shows a decreasing amount of chloritic material throughout the series.

33 to 43. Practically the same as preceding, the amount of chlorite in bunches varying greatly in different portions of the core. The color also varies somewhat but for the main part keeps its characteristic reddish brown iron stained character.

43 to 48. A breccia much the same as the one occurring at 27 feet, consisting of reddish brown trap fragments held in a bluish-gray, sandy ground mass. There is a considerable amount of calcite present in the trap, both as filling for small amygdules and as veins. The contact between the two is very rough and irregular. If the core portion is a sandstone it has been considerably baked by the presence of the trap. The texture of the sandstone is very fine grained. The character of the grain or its structure can not be determined. Chlorite is present to some extent in the trap fragments. Near the bottom of this member there is a distinctly chloritic band of an inch or so in width which occurs at an angle of about 45° with the core. The contact of this with the reddish trap which is adjacent to it is outlined by a thin film of calcite along it and the walls of the trap. This abundance of chloritic material persists nearly to 48 feet where the rock again becomes very similar to that from 30 to 43 feet, i. e., it is a reddish-brown trap with scattering bunches of chlorite throughout. Some of these chloritic masses also contain calcite of an earlier origin. Small veins of calcite ramify out from these bunches. Specimen No. 1 from this locality shows a small brecciated face to be about a quarter of an inch in diameter which is of a lighter color than the enclosing rocks. This portion is somewhat more porous than the hard, even textured trap on both sides. In this lighter colored portion are fragments of the wall rock from both sides. These fragments are very angular. Separated from this small brecciated band by several inches of a reddish trap already described is another band also of brecciated material. The main fragments here consist of the amygdaloidal fragments of trap and a considerable amount of calcite and epidote. Conspicuous in this fragmentary core is an amygdaloidal pebble which shows a coating of epidote around which is calcite. This may possibly be looked upon as amygdular filling. Drusy cavities occur in the chlorite portion which contain small indeterminate crystals. The rock below this becomes again a fine grained reddish trap but the chloritic masses are not nearly so abundant and the principal amygdules seen are filled with calcite. Some chlorite, however, is present. Separated from the preceding bed by presumably the same distance that separated that band from the preceding, is another brecciated band in which the characteristics are very much the same as those seen in the preceding; the cement in this case, however, is more of a calcitic material and the appearance of the rock leads to the belief that it is more of the type of vein breccia than igneous breccia. Underlying this breccia again occurs reddish brown trap

with a fair amount of chlorite and more amygdules filled with calcite. Veins filled with calcite also irregularly intersect the mass.

50 to 53. At 50 occurs a very reddish trap with numerous bunches of chlorite which stand out in prominent distinctness against the red back ground. There is also running through this reddish portion a greenish gray fine grained rock whose exact character is indeterminate. It irregularly intersects the reddish trap and the contact between the two shows numerous filaments of the greenish gray rock penetrating into the reddish brown. Horses of the reddish brown are also included in the greenish gray material. This gray rock appears to be similar to the greenish gray matrix of the breccia described near 27 feet. This band is presumably about six inches wide and is followed by a series of traps exhibiting much the same character as the preceding traps. Bands of chlorite, however, do not appear to be as large as the former.

53 to 58. The rock becomes somewhat less reddish than the preceding near the top and the cores are not in a much better state of preservation and the grain of the rock becomes slightly coarser. About in the center of this member the chloritic bands more or less completely disappear and the rock is much coarser grained allowing the determination of some of the constituent minerals but the rock shows considerable decomposition and the core reserved is quite broken up and remains only in small fragments. Towards the base it takes on a pseudoamygdaloidal structure for a few inches in which the amygdules are filled for the most part with chlorite and laumontite. Some calcite also appears and the area in which these amygdules are the most frequent is seen to be heavily charged with epidote and chlorite.

58 to 66. A dark moderately fine grained trap with a few chloritic bunches. Rock intersected by numerous small fragmentary veins of laumontite. In portions the chlorite has been altered into an iron compound which gives the reddish blotched appearance to the core.

66 to 68. About the same as preceding of slightly more reddish character. The base of this is represented by a sand which is too finely comminuted to make out the various minerals, but which has a very distinctly iron stained appearance giving it quite a red color.

68 to 78. At the very top of this member is an amygdaloidal trap, the amygdules being rather small and filled for the most part with a chloritic material. There appears to have been some brecciation in this case and the matrix which cements the various fragments together is of a lighter gray color than the trap fragments already mentioned. There is a considerable amount of chlorite, not only in the form of amygdules but also apparently in the lighter colored portion of the rock. Below this is a small band of dark, very massive trap of such fine grain that the various minerals are not distinguishable, which is followed by another brecciated band about the same as the preceding with a considerably greater amount of chlorite than that one. The cavities in the amygdaloidal portion are filled with quartz and calcite. The ground mass of the amygdaloidal fragments is of a very reddish color. This band is about 4 or 5 inches in width and is followed by a dark massive, slightly greenish band with some chlorite which in many instances has been altered to an iron mineral and appears as a reddish stain upon the rock. Succeeding this is a reddish brown trap with bunches of chlorite and sometimes calcite. This rock has about the same color as the fragments in the amygdaloid. There is a considerable amount of epidote and chlorite (principally the latter), present, and the whole series for a couple of feet shows more or less of the brecciated character, and the filling in many cases between the separate fragments is made up of greenish chlorite. In many places the rock becomes distinctly epidotic or chloritic and this is the only

mineral seen in may instances. The portion represented by this extremely epidotic part is perhaps eight inches in width. It is followed by a reddish brecciated band and then occurs some more epidotic rock for another foot. This in turn is again followed by a reddish brown trap moderately fine grained and then comes a third band of epidote of less width than either of the two preceding ones. This member is for the most part represented by small fragments from 68 to 78 feet, showing the fragmentary character of the rock and its inability to stand up under the influence of the drill.

78 to 88. The following series also consist of much broken up rock and the drill cores are in a very fragmentary condition. The top of this series is a reddish brown trap with the usual bunches of chlorite present. This is followed by reddish sand and fragments up to 81 feet where a brecciated rock, consisting of fragments of this same reddish trap, cemented together by chlorite and calcite, appears. The trap is seen to be broken across by numerous veins of calcite which may completely separate the various parts of a single fragment. This brecciated band contains a good deal of chlorite also and is succeeded by a very greenish layer composed almost entirely of epidote and chlorite. This is followed by another breccia band and this is underlain by another chlorite band which is of considerable thickness and alternates with various small portions of trap. This chloritic phase extends to nearly 88 feet; in portions being nearly all altered epidote, in other portions showing small brecciated bands. From 88 to 98 the top of this member consists of a much brecciated band, the various fragments being separated from each other by chlorite and calcite. In some portions there are drusy cavities in the chlorite in which small quartz needles protrude. The calcite seems to fill amygdules in this rock and the relative age of the two minerals is rather difficult to determine. This band extends for about four feet and is then underlain by a dark brown trap with a few small bunches of chlorite. The bulk, however, of the chlorite that occurs is disseminated in small fragments throughout the mass or does not appear in as large segregations as usual. About two feet from the bottom of this member occurs a highly epidotic band of about six inches in width which is underlain by dark brownish trap.

99 to 106. About the same as the preceding and with the amount of chlorite somewhat greater and collected together in larger bunches in the mass. The texture of this rock is moderately fine grained and the various members are not easily distinguished with the exception of the chlorite. Veins of calcite intersect this member in small number. At about 101 feet occurs a greenish chloritic rock with glittering faces of what is presumably calcite throughout it. The epidotic portion is represented by the core as about a foot in thickness. This is followed by a rock much the same as the preceding but with the chlorite in the upper portion in much greater excess than the former. The rest of this section is represented by comminuted fragments principally in the shape of sand which are barely determinable. The color of the sand is for the most part a brown, earthy color but it is in too small a state of subdivision to determine the various minerals.

106 to 112. A small band of chloritic material up to an inch or so in width followed by a brownish, much decomposed trap with some occasional bunches of chlorite. Following this nearly to the bottom of the member is a series of fine grained rocks which contain a considerable amount of epidote scattered with great evenness throughout the mass. This portion seems to show a distinct stratification which is due to a color banding depending upon the amount of iron present and the state of concentration with which the epidotic portion occurs and the so-called bands of stratification occur at a slight angle with the core, the angle of intersection varying considerably in different specimens. This member is cut by

numerous calcite veins of small size. The extreme bottom of this hole is made up of a dark fine grained trap with bands of chlorite. The trap has a slight bluish to purplish cast and contains quite a considerable amount of calcite. Calcite also is seen in small hair-like veins intersecting the ground mass. As a whole, all the cores from this hole have been very much broken up and many of them in the shape of sand. This may be due to the closeness to the surface, and is also in large part probably dependent upon the brecciated and fragmentary character of many of the members of the series.

Label on Box, Hole 1, 112 to 209. Stencil number, No. 2.

112 to 122. A grayish epidotic rock very similar to the one just preceding but not showing any of the stratification noted in the last. This extends for about a foot and a half and is then followed by a dark very fine grained trap with considerable amount of chlorite. This chlorite has in many instances been rubbed and the rock looks as though there had been some slickensiding through it. The bunches of chlorite are very irregular. This extends for about a foot and a half and then comes another chloritic or epidotic layer. On fresh fracture this rock shows areas of strong chloritization followed by darker layers in which there is not such an abundance of chlorite. The whole appears to show but slight tendency towards stratification as represented on cross-fracture. This stratification is seen to be due to the amount of epidote present. This yellow epidote band is rather thin and is followed by a brecciated band, the fragments of which are shown in an epidotic matrix. Succeeding this is a dark, very close, fine grained trap with some large calcite faces gleaming in cross-section. The sand from this rock is of a reddish color and much iron stained. Towards the base of this member the trap becomes more dark colored and the bands of chlorite somewhat increase in size.

122 to 132. The upper portion of this rock consists of a brownish trap with a considerable amount of chlorite scattered through the ground mass as well as appearing in local segregations of that mineral. This is followed by a greenish epidotic layer of two to three feet in thickness in which the epidote is seen to have been considerably altered towards a chlorite and to be in large part associated with calcite. The lower portion of this epidotic band runs into a brecciated portion which shows the same characteristics as many of the breccias previously described. The trap fragments included in this breccia are of a reddish color rather darker colored in the center than near the contact with the epidote. The epidote occurs for the most part as a matrix which holds the trap fragments. Calcite is also sparingly found throughout this portion. The epidote has numerous drusy cavities in which perfect crystal forms, both of quartz and epidote, are frequently noted. This brecciated band is about two feet in thickness and is followed by a small amount of epidotic trap which has a reddish green color due to the presence of the amount of epidote which is evenly distributed throughout this mass. Following this is a dark, moderately coarse grained trap which is succeeded by a lighter greenish gray sandstone-like rock which shows slight evidence of stratification. The contact between this part and the trap is seen to be very irregular, the trap entering it in irregular apophyses. The direct contact between these two members is marked by a reddish decomposed iron band which brings out the contact very prominently. The color of the underlying rock is considerably influenced by the amount of epidote which is present. Small secondary calcite faces appear in the lower part. This band is relatively thin, not exceeding two or three inches and is followed by a very dark trap.

132 to 142. A dark, rather fine grained, nearly black trap with few minerals

distinguishable in core, scattering bands of epidote present in the hand specimen. Thickness of this about three feet. Then comes a narrow band of epidote associated with some bluish gray rock previously noted in other breccias. This seems to be a thin brecciated band as shown by the presence of reddish amygdaloidal pebbles cemented together by a fine matrix of epidote and this gray sandy rock. The epidote occurs also in a band about an inch thick cutting obliquely across the core, then followed by dark, moderately fine grained trap similar to the preceding for about two feet where we again come into an epidotic horizon. The trap at this point is very greenish on account of abundance of epidote. In certain portions the epidote has become localized into large bunches, in some places forming the entire portion of the core. This is succeeded by a grayish brown trap with a few iron stains which probably remain pseudomorphic after some altered mineral. Chlorite although present is not very abundant. The bottom of this member is marked by the presence of another epidotic band.

142 to 154. A greenish, heavily impregnated epidotic rock cut by small veins of calcite, the texture of the whole being very massive and breaking with a subconchoidal fracture. Practically the only mineral distinguishable throughout this portion is the epidote and its alteration product chlorite. This is followed by a dark brown trap with a considerable amount of dark green chlorite present in large abundance. This chlorite is more abundant towards the top of the series than lower down. This reddish brown trap extends for about ten feet and is then followed by another epidotic portion to the bottom of the member. This epidotic portion is in all respects practically similar to the preceding but is cut by numerous calcite veins as well as a brownish vein which appears to consist of quartz or which may be calcite, as from it radiate out many small branch veins which are filled with calcite. There seems to be a slight color banding in the epidotic portion parallel to this brownish part which intersects the core at an angle of about 25°.

154 to 162. Grayish green, very fine textured rock in which the structure is not evident. The rock is a very dense, compact one and has been cut by some calcite veins which causes it to break into angular fragments. The thickness of this band as represented by the cores is only a few inches and it is succeeded by a dark brown trap with considerable epidote such as has been previously seen in this cross-section. This trap extends for a couple of feet and then is succeeded by another epidotic portion which extends for about one foot. The contact between this epidotic portion and the underlying rock is represented at 160 feet by specimen No. 1. The rock in contact with the epidotic portion is an amygdaloidal rock, the amygdules being of rather small size and somewhat irregular outline. Amygdules filled with calcite and laumontite. Considerable chlorite is present in the amygdaloid. The amygdaloidal portion is seen to extend into the trap for a distance of about one-half to three-fourths of an inch only. Away from the contact the rock rapidly becomes fine grained trap with a few scattered bunches of chlorite.

162 to 172. A very dark grained, massive rock considerably broken up as represented by the drill cores, containing only a small amount of chlorite, towards the base becoming somewhat luster mottled. Its poikilitic character is seen to be very fine in character, the small luster mottled portions being only a fraction of an inch in diameter.

172 to 190. Trap very much the same as preceding, slightly coarser grained with a dark reddish color or nearly black for the most part. The luster mottling is distinctly noticed throughout this series although still of a very small size. The cores representing this portion of the whole are considerably longer and stronger than those of the other portions but still the rock shows a decided tendency to break up. The lower portion of this member contains somewhat more chlorite than the

upper part but is considerably more broken up than the upper portion. Veins of calcite are practically wanting in this part and are only rarely seen cutting the core at a rather high angle.

190 to 209. Rock practically the same as preceding with a less decidedly black color, approaching nearer to a reddish brown. The upper portion of this series shows the same luster mottling on the same small scale throughout all the cores. In the central portion of this member the rock becomes slightly more epidotic, but the epidote appears to be a vein cutting across the formation. In some instances there is a large amount of chlorite and parts of this chlorite appear to afford a slickenside surface.

Label on box Hole No. 1, 210 to 299. Stencil number No. 3.

209 to 219. A dark trap somewhat more poikilitic than preceding with faces on which chlorite appears cutting the core at an angle of about 45° but with small amount of chlorite otherwise through the mass, succeeded by lighter brown trap (showing less poikilitic markings) most of which is preserved in the drill record merely as sand. This sand is of a light brown earthy color in which the fragments are seen to be of practically the same character as the faces of the rock immediately above. Towards the base the poikilitic structure again appears rather predominant but the size of the mottling is rather small. The trap grades towards the base into a darker. more compact trap in which about the only minerals recognizable are the cleavage faces of the augite. Chlorite is seen abundantly along joints on the face of this trap and towards the extreme base the rock takes on more of the greenish cast due to the presence of the evenly distributed epidote.

219 to 229. A somewhat coarser luster mottled trap than preceding with a dark, nearly black color. Considerable calcite, but few veins of calcite were seen cutting the mass. On fresh fracture the augite faces are about the only minerals to be distinguished. Chlorite is seen abundantly on joint faces of a black lustrous character. Towards the base of this member the sand derived from this rock is of the same greenish cast but the rock still appears to maintain its black color. Chlorite is seen abundantly throughout the ground mass of this rock.

229 to 230. Rock very similar to preceding but with the luster mottled areas much more closely crowded together and of smaller size. Seams of chloritic material cut the rock irregularly in all directions. Chlorite is also seen abundantly throughout the ground mass. Color on fresh fracture is dark, trap rather massive. The sand from the same from near the base of the series takes on a much lighter color but does not show the green tint noted in the preceding. Again all the drill record preserved in this part is in the shape of sand and small broken up fragments of core so that the record is very unsatisfactory for this portion of the whole.

239 to 249. A greenish much more epidotic trap, the epidote seeming to show rather a sharp line of demarkation from the preceding trap. The sand from the same is of very greenish color. Veins of quartz and calcite cut the bed rock and branching strings of the same material give the green epidote almost a brecciated appearance. These strings seem to radiate out in all directions, in some cases the vein filling enclosed portions of the green epidotic rock. The distinctly epidotic portion extends for about three or four feet and is then succeeded by a dark greenish trap but the presence of epidote is plainly to be noted in this rock and shows that it owes its color entirely to the presence of this mineral. Small amygdular cavities are noted being filled with calcite. These amygdules have a regular outline and vary considerably in size. The whole mass is seen to be cut up by a net-work of

calcite veins which as a general rule extend parallel with the longer axis of the core. This èpidotic trap extends for about two or three feet and then the amount of epidote gradually diminishes and the trap becomes more of the ordinary dark brownish variety. Sand from this portion of the record shows a reddish iron stained character. Bands of more or less epidotic trap occur throughout this part separated from each other by bands of varying thickness of a reddish to a brownish trap. Below the epidotic portion, about 247 feet, is a dark, very fine grained, massive trap, nearly black in color, with a considerable amount of chlorite on fresh fracture. Succeeding this is a member of more or less luster mottled trap of much the same character as the preceding portion of the column. The luster mottling in this member is of rather small size and the various augite crystals are closely crowded together. Chlorite is abundantly present and seems to show that some slipping movement has taken place along it on account of the curving and striation on the surface. Bunches of chlorite occur localized throughout this member but for the most part it does not occur in the bed of the rock, being rather limited to joint faces and planes of this character.

249 to 259. The upper portion of this member consists of a trap of a general darkish color, the sand from which is a somewhat lighter rusty brown and the trap is moderately coarse grained and shows a slight luster mottling. The luster mottling is, however, very small in size. Towards the central portion of this part, the mottling becomes somewhat coarser and the rock is of a much darker color than the preceding and individual augite faces are easily distinguishable and the whole mass has a much coarser texture than the upper portion. The sand from this portion of the bed is of a brownish earthy color with considerable amounts of limonite, probably due to the alteration of some of the iron constituents throughout it. Calcite fragments are also to be distinguished in the sand; some chlorite is present throughout the cores, but it is seen in no large bunches. The amount of luster mottling seems to locally vary, here and there heavily luster mottled bands being separated by bands much less poikilitic. In the portions which do not exhibit the luster mottling the trap is seen to be a very hard, dense, black structureless trap.

259 to 268. At the extreme upper portion of this member the luster mottled trap gives place in large part to ordinary trap which seems to show considerable amount of irregular color banding. Portions of this dark, rather massive trap are seen to be cut by a lighter colored rock which cuts it in irregular apophyses. A light colored rock appears in No. 7 of this series to be indurated into the trap. This light colored rock is a very dense, massive rock showing no evidence of structure other than as stated. The presence of this lighter gray trap has in some instances given the darker trap the appearance almost of brecciation but they seem more like small dikes or veinlets cutting the mass than true breccia. This phase only extends for a foot or so, and then is succeeded by a very dark, rather massive trap with a few amygdules, the amygdules being filled with calcite for the most part. Very irregular blotchings are noted, however, on the shorter core which are filled with chlorite. Succeeding this portion comes another band very similar to the preceding and showing the same brecciated appearance. The dark trap in some cases in contact with the lighter rock shows amygdaloidal cavities near the contact and becomes, further removed from it, a dark massive trap. The fragments are rather irregular in shape and show sharp corners. This phase appears to persist to 264 feet, where it is underlain by a dark greenish, nearly black trap, with considerable amount of chlorite on jointed surface. Some chlorite is also present in irregular bunches throughout the mass. On the upper portion of this member the rock seems to be considerably decomposed and the minerals on the joint faces

exhibited are laumontite from which small strings of calcite radiate. These calcite veins often times appear to be also in the form of gash veins and some of them apparently show a slight off-set. There are a few irregular amygdules also which are filled with calcite.

Near the lower end of this member the trap becomes somewhat less dark in color but the amount of chlorite remains about the same and is easily recognized by its black shining color on many of the joint faces. Veins of calcite frequently intersect this member. At the extreme bottom of this member the rock becomes much more greenish and is cut by large veins of calcite and laumontite. Chlorite is abundantly present throughout this portion, both in regular fragments and also evenly distributed throughout the ground mass.

268 to 278. The upper portion of this member consists of a somewhat brecciated band in which the prevailing color is a reddish brown. Darker fragments of a somewhat amygdaloidal rock, with amygdules filled with calcite are seen, as well as fragments of a dark reddish trap. A considerable amount of calcite in small particles is also scattered throughout the matrix which is of a brownish red, sandy character. The thickness of this bed is only four or five inches, but it is succeeded by a very greenish amygdaloid. The contact between the amygdaloid and the breccia looks to be distinctly an igneous one. Masses of the greenish trap are included in the brown breccia and fragments of a brownish rock enter a greenish amygdaloid in many irregular apophyses. The filling of the amygdules of this amygdaloid consists principally of quartz. Almost all the specimens are intersected by numerous wide veins of quartz with a general direction parallel to the longer axis of the drill core. The thickness of this amygdaloidal band is somewhat under six inches and is followed by a brownish red breccia. The fragments in this breccia appear to be composed for the most part of irregular masses of trap which have been considerably decomposed and altered, the result being a decomposition of the iron minerals or their consequent remains in the shape of a limonitic stain. Calcite is also abundantly frequent throughout the mass. Small veins of calcite radiate out from the larger bands of the same mineral promiscuously cutting the rock in all directions. The texture is rather even and somewhat sandy. On fresh fracture the rock has much the appearance of an amygdaloid with a sandy matrix separating the various constituents. The thickness of this member is 8 to 10 inches and then a brownish green amygdaloidal rock succeeds it. This rock has a considerable amount of calcite as a filling for the amygdules and also some small hair-like veins cutting the rock generally in its longest direction. The color of this member varies considerably owing to the decomposition of the irons. The shape of the amygdules is rather regular but the amygdules are, all of them, small and sparingly disseminated throughout the specimen. In one portion a band about one-half inch wide of calcitic material, weathered to a rusty brown color, cuts the mass at right angles to the drill core. Below this comes a dark, nearly black, greenish trap with a few irregular amygdules of calcite in its upper portion and also a large amount of chlorite scattered in irregular bunches. The calcite seems to be both older and younger than the chlorite, probably marking two stages in the development. Laumontite is also seen on joint faces cutting the rock. The calcite appears in numerous small thread-like veins. Farther away from the contact of this rock with the overlying amygdaloid the rock becomes more distinctly a fine grained, dark trap with few amygdules, and grades from this type into a dark, nearly black, somewhat loosely luster mottled trap. The luster mottling, however, is seen to be rather in the form of local stages, being sometimes present and sometimes almost wanting. This rock is a reddish brown amygdaloid. Amygdules are filled with calcite almost entirely. Small veins of calcite also intersect the rock at a slight angle to its longest

direction. In some instances the amygdules are filled with chlorite and in this instance the chlorite seems to be in the form of little balls which on breaking the rock, leave the matrix and stand out as rounded pellets or leave bullet-like depressions in the matrix. At about 274 feet, the rock becomes much less amygdaloidal, although a few amygdules of small size, filled with calcite still persist. The rock has become somewhat darker colored and lost much of the reddish cast previously noted. Veins of calcite also intersect this member in much the same direction as noted in the preceding. The amygdaloidal portion dies out and the rock becomes dark greenish, nearly black trap with considerable chlorite represented on the joint faces, and also scattered in irregular masses through the mass. The powder from this member is of a somewhat lighter color of a dirty earthy brown in which a few minerals can be seen—specks of calcite and some of an iron silicate. Underlying this is a very massive dark greenish amygdaloid. The filling of these amygdules is in large part quartz, although some calcite is also present. Plates of calcite also glitter throughout the ground mass of this amygdaloid. Small thread-like veins of calcite are seen radiating from one group of amygdules into another and the whole system seems to be thus connected. This amygdaloidal portion seems to be of rather small width as represented by the core, not being over a couple of inches and is succeeded by a breccia in which various igneous fragments are cemented together by a brown sandstone. The sandy portion consists of a dark brownish, somewhat reddish, very fine grained massive rock which is impossible to determine on cursory examination. The fragments included in this consist of a dark reddish brown trap with a considerable amount of chlorite in irregular patches. The contact between these fragments and the sandy material is almost perfectly outlined by masses of calcite.

Reddish trap pebbles are also present. Where apophyses of this latter have extended out into the sandy material there seems to have been a great decomposition of the irons and there is a little halo around each division of a yellow band extending into the yellow color as the matrix. This portion is of rather small extent being indicated in a drill core as merely an inch or so in length occurring at about 277 feet, and then comes an amygdaloid with amygdules filled with quartz of somewhat greenish color, but slightly more reddish than the preceding amygdaloid. From here to the bottom of the member the rock is a trap of a somewhat open texture with amygdules in the upper portion filled with calcite, but passing in depth into a less amygdaloidal portion in which the rock is a greenish, nearly brownish black fine grained trap. Veins of calcite frequently intersect this member parallel with its longest axis. Bands of chlorite are frequent in this portion.

278 to 288. The upper portion of this member consists of a breccia very similar to those previously described which is intersected by numerous calcite veins of small width. The fragments seem to have less angular outline than those immediately preceding. This is of rather small extent and is followed by a dark reddish brown amygdaloid in which the filling of the amygdules is for the most part of calcite. Some prehnite is also present and chlorite is also observed in small quantity. The shape of these amygdules is rather regular. This has a thickness of about one and a half feet and is followed by a dark, rather massive, fine grained trap with bunches of epidote in large rounded fragments. Calcite is also present and where present is seen to be older than the chlorite. The chlorite exhibits the feature so often seen of splitting out of the matrix and leaving impressions in the shape of spheroidal dents in the place from which one of these chloritic balls has been knocked out. Calcite is also sometimes found in the scattered amygdules which occur throughout this mass. In character, however, the rock grades in depth into a dark trap with very few amygdules. At about 283 feet the record is represented solely

by a brownish red colored sand which is of such fine texture that it is impossible to state the rock from which it is derived.

This is immediately followed by a greenish sandstone of very fine texture. This is a questionable member as it is very highly charged with epidote and looks very similar to some of the felsites which were found near the location of the United States Mining Company The contact between this member and the amygdaloidal portion of the trap which is not connected with it is marked by a reddish, much iron stained zone which extends from the trap into the sandstone. Veins of calcite are seen passing from the trap into the greenish brown rock into thread-like forms. The exact contact with the sandy material is represented by a thin one-sixteenth of an inch band of very massive trap. Above this occurs a line in which amygdaloidal cavities are very frequent. Beyond this amygdaloidal portion the rock appears to turn into a greenish chloritic trap which we have previously noted. The sandy portion is very much decomposed and many of the former minerals are represented by limonitic deposits throughout this mass. No evidence of stratification is observable and it seems highly probable to my mind that it is in reality a sandstone. The thickness of this bed is only about six to eight inches and the lower contact with the underlying trap is represented by a series of amygdules oriented nearly parallel with the contact. These amygdules seem to be confined not only to the trap but also to extend into the so-called sandy member. The amygdules are filled with calcite and are for the most part very small. Underlying this member is a dark, nearly black, rather massive, somewhat decomposed trap, showing almost no constituent minerals with the exception of chlorite. The core preserved from this dark trap is in a very fragmentary condition and shows to what an extent the decomposition had proceeded.

288 to 299. In the upper portion of this member, the trap becomes somewhat lighter although still of a very dark color. The texture remains about the same, very fine grained rock with none of the constituent minerals recognizable. This portion represents various phases, in which there is a more or less decided tendency towards a darker color, but this may be regarded merely as local stages and not as being of any particular importance. In portions of this rock there are small amygdules which are filled with calcite. The irregular blotches of chlorite which occur throughout this whole member appear to have been contorted somewhat parallel to the length of the drill hole. About in the center of this member they cut a small half-inch band heavily impregnated with calcite which has been decomposed into laumontite or possibly some of the zeolites.

Throughout this whole series from 210 to 299 the drill record has been very fragmentary, showing the rather broken up character of the rock. The drill cores are extremely fragmentary, seldom exceeding a couple of inches or so in length, and much is simply preserved in the shape of sand.

Label on Box, Hole No. 1, 299 to 342 feet. Stencil number, No. 4.

299 to 309. A brownish, moderately fine grained trap with some bunches of chlorite of small size. Rock intersected by a few veins running at right angles which show laumontite on joint faces. Also intersected by another series of veins running nearly parallel with the longer axis of the core. Chlorite is often seen on joint surface and some serpentine. Towards the lower portion of this member the rock becomes more dark colored and slightly coarser. In part this coarser textured trap shows slight luster mottling but the luster mottling is rather small in size and does not appear to be continuously distributed throughout the member,

being in patches here and there separated by bands of a grayish brown trap before mentioned.

309 to 317. A trap much the same as preceding but with a slightly more greenish tint. Luster mottling is apparently wanting in the upper portion of this member. The grain is rather fine, none of the minerals with the exception of chlorite being recognizable. Near the central portion of this member there is a four inch band of more distinctly greenish trap which is very fine grained and shows some sparkling calcite faces. Below this portion is a slightly amygdular part with rather large, irregular amygdules, filled for the most part with calcite but with some epidote associated with it. At about 313 the rock becomes much coarser grained and the luster mottling is of marked appearance. The mottled portions stand out in light color against the darker back ground. These luster mottled portions are much larger than any in the column heretofore described. Just below this central luster mottled portion is another slight amygdular band, amygdules of much smaller size and inconsiderate extent filled with calcite. Irregular veins of calcite intersect this member both horizontally and vertically, and oftentimes occur so close together that they have broken up to some extent the country rock, leaving it in horses surrounded by a vein filling. This luster mottled portion has a much more reddish brown tint than the preceding traps. Towards the lower portion of this member the luster mottling is less distinct and the trap is represented by a rather fine grained, very dark trap with a few small cavities filled with calcite. Numerous radiating veins of calcite also intersect the core. Some chloritic bands are observable on the polished surface of the core. The veins of calcite which intersect this member are small in size, rarely being much more than a hair's width in thickness and they seem to cut the rock in all directions and to make it much broken up.

317 to 327. The upper portion of this part is practically the same as the preceding, some laumontite being noted on joint surface or vein fillings, followed at 321 feet by a dark brown amygdaloidal rock, the amygdular cavities being rather of small size and of somewhat regular outline filled with calcite and laumontite. Calcite shows an alteration to the latter mineral. Following this is a luster mottled portion consisting of a dark brownish trap of moderately coarse grained texture with considerable amounts of chlorite present in various sized bunches scattered irregularly. The abundance of the chlorite present has given a somewhat greenish tinge to the rock. Veins of calcite are also noted here and some quartz veins. Scatteringly interspersed through this member occur moderately large, rather regular shaped amygdules filled with calcite. The veins which cut this member for the most part run horizontally with the core. The luster mottling is seen to be more or less of a localized feature, the more mottled portions being separated by bands of a reddish brownish green trap already described.

327 to 337. Much the same as preceding member with the mottling somewhat more pronounced than in the former. Veins of calcite also noted intersecting this member nearly parallel with the longer axis. These veins also carry some quartz. Originally the rock was rather high in epidote and its remnants are seen through the presence of chlorite pseudomorphic after it. Towards the center of this member the brownish color is somewhat less marked and the rock becomes of a decidedly more greenish color. The texture and general characteristics, however, remain practically the same. In cross-section some of these cores show a slight tendency towards banding through flow structure. In the lower portion of this member the mottled character disappears to a great extent and on fresh fracture shows a larger percentage of calcite than in the former portions. This calcite it must be understood does not occur in the form of veins but principally as secondary crystal

forms in the ground mass. The grain becomes slightly coarser towards the bottom and almost all the constituent minerals are to be recognized.

337 to 348. The upper portion of this horizon consists of a light colored, brownish trap with a few large irregular amygdules filled with calcite. This portion is also considerably cut up by calcite and there has been some enrichment of the ground mass from the vein. The rock has a distinctly open texture. Small segregations of chlorite are rather abundant throughout specimen. The iron appears to have been much decomposed and their remains appear as reddish blotches on the mass. This gives a somewhat speckled appearance to the upper portion of the member. Below this the rock becomes very coarse grained and shows a considerable amount of characteristic diabase minerals. The core from this portion becomes much more compact and less broken up. Some luster mottling is also present. Towards the central portion, however, the luster mottling is not nearly so marked. The speckled character of the rock is largely lost; the grain, however, remains relatively coarse. Chlorite is abundant throughout the specimen, but veins of calcite are not of such common occurrence. At about 346 there is an amygdaloidal portion, the amygdules of rather small size, in a dark, decomposed matrix. This rock is so badly altered that only a small portion of it is preserved in the drill record. Presumably the amygdules are filled with calcite or its alteration product, laumontite. As represented by the core this member only consists of a band of about an inch in thickness. This member is immediately succeeded by a dark greenish, fine grained trap, but this soon gives place to rock the same as that which lay above it. Very near the bottom of this hole, this greenish trap showing a large amount of chlorite and serpentine, is cut by a small band only poorly represented on the core of a reddish, sandy looking rock, much the same as the matrix of the breccia which occurred in the earlier part of the series. The contact between the two is somewhat irregular, portions of a greenish trap projecting rather irregularly into this sandy portion. This light greenish, brown colored rock is very similar to the felsite already noted from near the United States mine. The extreme bottom of this member shows another band similar to the one just described, but separated from it by a dark, very much decomposed trap of moderately fine grain in which the individual members are not separable. This is cut practically parallel to the longer axis by calcite veins.

348 to 357. A dark trap cut by veins with laumontite on surface is the top of this member, but it is soon succeeded by a greenish gray amygdaloidal rock, the amygdules in this instance being filled with quartz. Veins of calcite with some quartz filling also intersect the core. The amygdules are of rather small size. A large amount of chlorite is present and in the bottom of this portion the amygdaloid has an outer envelope of epidote which is earlier than the quartz filling. The thickness of this band, however, is rather slight and is immediately succeeded by a rock represented in the drill core as a very reddish brown, earthy colored sand. The determination of the original character of this sand is very indefinite. The first fragments which are large enough for determination in this amygdaloidal part occur at 351 feet and consist of a dark greenish, rather fine grained trap, with numerous, rather large bunches of chlorite. Veins of calcite frequently intersect the mass. The bands of chlorite have given a somewhat greenish color to this portion. There is then a very much decomposed, much iron rusted portion of a reddish brown trap. This shows great decomposition and affords a poor basis for the determination of original characters. There is a small band of greenish epidotic rock represented in the core by about an inch of material which is of very fine grained, even textured rock, showing practically no other constituents than epidote, but this is followed by a dark, much decomposed amygdaloid, the amygdules being filled with

calcite or its alteration product, laumontite. Underlying this at about 354 feet and extending to the bottom of the member is a brownish sandstone with the stratification poorly shown. The sandstone contains, in part, more or less epidote, which has given it locally a very greenish color. The texture of the mass is very fine grained and remarkably even. Veins of calcite intersect the mass nearly parallel with the cross-section of the core. The lowest portion of this member shows the contact of this brownish sandstone with a greenish amygdaloidal rock. The contact between the two is rather even, although apophyses of the green amygdaloid extend into the sandstone. The amygdules are for the most part rather regular in outline and are filled with quartz.

357 to 367. This brecciated appearance still exists in the upper portion of this member but the sandy portion is much less, and the rock has distinctly a greenish amygdaloid with amygdules of small size. Most of the amygdules are filled with calcite and quartz. The rock has a very greenish color owing to the large amount of epidote present. The thickness of this band as represented in the drill record is not over a foot at most and is succeeded by a dark greenish gray, luster mottled trap. This trap contains a large amount of chlorite scattered in rather regular bunches, irregularly throughout the mass. A few very small scattered amygdules filled with calcite are also to be noted in the upper portion but the amygdular member of the portion rapidly fades into a dark, fine grained trap with few of the constituent minerals recognizable. Chlorite is abundantly present throughout this upper portion. The luster mottled phase is, as usually occurs in rather localized bands, separated by portions not so conspicuously luster mottled. This phase extends to about 364 feet, where the rock passes into a reddish brown amygdaloid much iron stained on weathered surface. On fresh fracture this rock is seen to be a dark brown one, with the amygdules filled both with calcite and quartz, but the calcite has in large part been altered towards laumontite. Later than the calcite filling of the amygdules, some chlorite has been introduced. Veins of calcite intersect the mass and radiating out from these veins are numerous small fragmentary veins which seem to lead to the various amygdules and connect one amygdule with another. This upper layer shows numerous brecciated faces with the same characteristic brownish sandy rock, cutting diagonally through the core. Near the contact between these two members the amygdaloid is seen to have its amygdules more abundantly dispersed near the contact of the two formations. A reddish brown, iron stained horizon also makes the line of contact more prominent. The sandstone is very fine grained and compact. As represented in the drill core this phase does not extend more than a few inches. The best example of this may be seen in cores 363 to 367, No. 12. Also down in this amygdaloid the color changes from the brownish iron stained character of the upper portion to a more dark colored ground mass. The amygdules here are for the most part filled with quartz. At the very base of this series the amygdaloid gradually dies out and is present in a dark brownish, slightly amygdaloidal trap, the amygdules in this trappean portion being very small in size and of not great abundance.

367 to 380. The upper portion is a dark reddish brown, slightly amygdaloidal trap about the same as at the bottom of the last portion described. Abundant irregular masses of chlorite, the irons somewhat weathered, giving the rock a rusty speckled appearance. This is succeeded at 370 by a much coarser variety of the same rock, showing also slight luster mottling. At 371 this grades into a dark greenish, fine grained trap with scattering amygdules filled with quartz, much cut up and intersected by calcite veins. In the thin faces there has been a considerable development of chlorite. A few scattered amygdules of rather regular outline are also noted throughout this portion. At about 375 this fine grained rock gives

place to a somewhat coarser, dark greenish trap, with a considerable amount of chlorite in this portion; however, amygdules are sometimes found filled with calcite and some chlorite. A much decomposed band has passed through, presumably of the same character, and then to the bottom of this member the rock remains a dark grayish, somewhat greenish trap with a slight tendency towards luster mottling.

380 to 392. Upper portion of this member consists of a greenish amygdaloid, the amygdules filled with quartz. Laumontite is also present as an alteration of the calcite which also sparingly occurs. There is a large amount of chlorite present which is seen both in the amygdules and also evenly disseminated throughout the rock, giving it a somewhat banded greenish character. Some of these amygdules still have open cavities in the central portion. The amygdaloidal portion of this rock shows considerable variation between the amygdaloid and trap, the more amygdular horizons, being separated from each other by bands of trap in which amygdules are relatively rare. At about 385 feet the rock becomes much more reddish brown than preceding portion, the amygdules are much more scattered and those amygdules filled with calcite and quartz are of large size. The lowest portion of this amygdaloid ends at about 386 feet and is a greenish, fine grained amygdaloid with some rounded bullet shaped particles of chlorite, which on fracture leave the rock and stand out in nodular projection. The central portion of this member shows a few much scattered amygdules filled with calcite and quartz, but the most abundant mineral throughout it is a chlorite which occurs in small local segregations throughout the whole mass. At 389 feet this amygdaloidal portion entirely vanishes and to the bottom of this member the rock remains a dark greenish, moderately coarse grained trap showing in portions a somewhat luster mottled character. The chlorite is still abundantly present, both sparsely disseminated throughout the ground mass in irregular bunches and also as a coating upon the joint faces which intersect generally nearly horizontally these cores.

Label on Box No. 1, 393 to 470 feet. Stencil number on box, No. 5.

392 to 393. A dark greenish trap with considerable amount of alteration towards a chloritic material.

393 to 401. A dark luster mottled trap yielding a good core. This rock is a moderately coarse grained diabase with many of the constituent minerals recognizable in the hand specimen; contains a few bands of chlorite scattered irregularly throughout core. Towards the base of this member the trap is seen to be intersected by a few seams of calcite and laumontite. after which the mottled character of the rock becomes somewhat less distinct and the fragments of core are considerably broken up. At the very end of the series the chloritic bands seem to be somewhat more numerous and the core is only represented by small fragmentary chips.

401 to 410. This is a very massive trap of moderately fine grain, showing a considerable amount of chlorite throughout the ground mass. This member shows slight luster mottling in part which increases with depth. The cores are represented especially well by fragments, the shortest of which is nearly eight to ten inches in length, showing the massive character of the rock. On fresh fracture the rock is seen to have a dark, greenish gray color with augites slightly noticeable in cross-section. At the base of this member the trap is seen to be somewhat intersected by calcite veins with some laumontite also on surface. The extreme base of this series is marked by much smaller, broken-up cores.

410 to 416. The trap has almost entirely lost its mottled character and is a very

compact, dense, dark rock showing such a moderately fine grained structure that the individual minerals are not distinguishable in the hand specimen.

This member is very much the same as the last, except that it has no luster mottled character. The amount of chlorite distributed through these cores is somewhat greater than any before noted in this section and there are also bunches of calcite. On fragment No. 7 of this same series we come into an amygdaloidal belt, with amygdules of rather irregular shape filled with calcite. The amygdaloid has a general purplish gray color. In specimen under examination a large bunch of epidote altered to a chlorite is seen. There is a somewhat greenish cast given to the rock on account of the presence of epidote. Drusy cavities are also seen in which small epidote needles appear crystallized out into the cavity. A vein of calcite is also seen intersecting the amygdules as though of later origin. Towards the base the purplish color becomes less marked, the amygdaloid becoming considerably more brown and the amygdaloid seems to be fairly well consolidated and to hold its own under the action of the drill, but not nearly so well as the trap cores represented by fragments an inch or so in length. At the very base the core is considerably more broken up and the amygdules become less and less scarce, the very lowest portion consisting mainly of trap. A small amount of laumontite is seen near the very base of this member.

416 to 421. A moderately coarse grained trap on exposed surface having a brownish color. On fresh fracture showing distinctly a greenish tinge on account of amount of chlorite present. The core from this member is exceedingly good and in long fragments. Bunches of chloritic material with a decided envelope of calcite are seen at certain very rare intervals throughout the length of this column. Veins of calcite and laumontite also intersect this member, some of them occurring at about right angles with the long axis of the core. At the bottom of this member beds become very fragmentary.

421 to 426. Rock very similar to preceding with the exception that the texture is rather less coarse grained than in the one previously described. A few large, irregular amygdules of calcite are seen in this member but they are relatively coarse. Near the base of this member the rock becomes more amygdaloidal and has a much more reddish color, the amygdules are scattered sparingly throughout the mass and have a rather regular outline. Amygdules are filled in part with calcite and also some chlorite. On fresh fracture this rock is seen to have a very reddish color. Some of the amygdules are of extremely irregular shape. Towards the very base of this member the amygdaloidal character becomes less and less prominent until very near the bottom the rock is represented by No. 15 of this series simply as irregular masses and blotches of green chlorite, and wherever amygdules do occur, they are in very large irregular shapes. There is a large bunch of prehnite occurring here which carries some copper in small fragments scattered throughout it. It appears as though the copper occurred in certain druses throughout this vein material. The rock then passes on in very small fragments, much broken up, of the same kind of reddish trap with chloritic bunches and a few irregular amygdules to 426, which is very similar to the preceding, then comes a reddish gouge of clay which seems to afford no evidence of its original character. From 426 to 432, the rock is a dark brownish trap with very few chloritic bunches sparingly scattered throughout the core. This member is somewhat broken up by veins of calcite and laumontite. Then comes another mass or gouge which has a more or less reddish color. This latter is succeeded by a somewhat greenish amygdaloid as is shown by No. 5 of this series. There is then at the very base of this member a greenish sand probably derived from the sand pump and not to be considered as a gouge, which is apparently principally composed of epidote or chloritic material.

432 to 434. The top member consists of a dark trap somewhat intersected by calcite veins, followed by somewhat brownish green sand, which is very similar to the sand described in the preceding member, but the greenish cast is not so pronounced. This sandy member is then followed by a more compact, brownish trap, with a few irregular bunches of chlorite much the same as the preceding. On fresh fracture this trap is seen to have a distinctly reddish tinge. The bunches of chlorite are generally of small size, but distributed rather evenly throughout the mass, but in some instances there has been a local accumulation and the chlorite is preserved as quite a considerable bunch. This member is also considerably intersected by veins (which cut the core longitudinally) of calcite with some laumontite. The base of this member is very well consolidated as is shown by the length of the core which is about one and a half feet.

434 to 443. This member is very similar to the preceding with the exception that it shows a somewhat fine grained luster mottled appearance. Bunches of chlorite enclosed by calcite occur at rare intervals throughout the mass. The rock on the whole is moderately coarse grained. The cores preserved are of good length, sometimes running up as much as a foot or more. On fresh fracture the rock is seen to be moderately coarse grained, but of a reddish brown color.

443 to 445. A brownish red, moderately coarse grained trap, very similar to the preceding member. Bunches of calcite and chlorite are practically wanting throughout this member and the rock is only slightly intersected by calcite veins. The luster mottled character of the rock is fairly well seen.

445 to 453. This member is very similar to the preceding, the luster mottling being somewhat coarser towards the top but gradually decreasing in amount as we descend the series. In the central portion of this member the bunches of chlorite become of considerably greater size, but as we still descend the series, this chlorite does not become so apparent and is scattered more sparsely throughout the core. The luster mottled character which the rock loses in large part near the central portion of this member, becomes somewhat more pronounced as we near the base. On fresh fracture the rock is seen to have a moderately coarse grained structure. Examining under the glass there seem to be certain metallic bands throughout this trap as is shown in core No. 39, which from their color and general appearance would seem to be copper. They are so minute, however, that it is impossible to state positively their character. At the very base of this member the luster mottling again disappears to a considerable extent as is shown by No. 36 of this series. There is a small band of calcite intersecting this member. Thickness seems to be one-eighth of an inch.

453 to 456. A brownish red trap with a considerable number of bunches of chlorite throughout the core, the cross-section of these bunches showing them to be approximately spheroidal. This member is intersected by a number of veins of calcite which would allow the mass to be broken up to a great extent. There is some evidence of slickensiding, but it is very slight.

456 to 459. A brownish amygdaloidal trap of the upper portion which grades downward into a more typical amygdaloid. The thickness of the amygdaloidal portion as represented by the core is, however, rather unsatisfactory, not being much over a foot, and then grading downward again into an amygdaloidal trap, followed by an ordinary trap. The amygdules are rather irregular in outline and of moderately small size. The filling seems to be for the most part of calcite which is of a reddish color. Amygdules filled with chlorite are also seen but they are of relatively small size and of slight importance. As noted above this member grades down into a trap at the base of the series which is of a dark, very compact character. The individual minerals are not recognizable to the unaided eye. On fresh fracture

the rock is seen to have a very dark greenish color due to the presence of a considerable amount of small particles of chlorite. This rock is intersected by numerous veins. Scattering amygdules occur often through this trap but are relatively scarce.

459 to 461. Is a dark brownish trap with small bunches of chlorite. Epidote is also abundantly present and No. 5 of this series is represented by a purely greenish epidotic sand. This is very much more epidotic than the sand described above in the portion 426 to 432. To all appearances, this sand is principally composed of epidote. The fragments of cores succeeding this sand are seen to consist entirely of epidote (with numerous drusy cavities in which epidotic needles project) and also some quartz. The epidote seems to be very much broken up through drilling but this is principally due to the open character of the rock on account of the numerous drusy cavities. These cavities are of relatively small size and of extreme number throughout the specimen.

461 to 466. The very top of this member consists of an epidotic rock exactly similar to that previously described, merging gradually into a reddish brown trap of moderately fine grain, with a considerable amount of epidote present in the trap. This epidote is easily recognized throughout the member on account of its color, and the needle-like forms in which it is crystallized. Many of the druses in the upper portion of this member contain numerous well crystallized needles of this mineral. Passing downward the rock becomes more reddish brown and somewhat coarser grained. Veins of calcite intersect the mass and show a peculiar pressure twinning. Bunches of chlorite are here and there abundant and are of sparse dissemination throughout the cores.

466 to 470. Is a more coarsely grained trap showing in the upper portion a rather small luster mottled appearance, which in the central portion is not so well pronounced, and gradually decreases in extent as the base is approached. This member is also considerably intersected by veins of calcite with laumontite on the faces. On fresh fracture the rock has a distinctly reddish color but the constituent minerals are not easily determinable, although feldspars of a long vesicular type seem to be present.

Label on box. Hole No. 1, 470 to 555 feet. Stencil number, No. 6.

470 to 476. A reddish brown trap with a considerable amount of chloritic material scattered in irregular masses throughout the core which has given the rock a distinctly greenish cast. The texture is moderately coarse grained near the top; as greater depth is approached the rock becomes more luster mottled and in some instances is a distinctly coarse grained, poikilitic trap with a greenish cast. The greenish character seen in the luster mottled portion is not due to the large bunches of chlorite that are seen in the upper portion, for here the chlorite is more finely disseminated throughout the whole ground mass and is not collected into separate large sized bunches. This luster mottled portion is much more dark colored and has lost the reddish cast that was present in the upper portion of the bed. Veins of calcite and laumontite do intersect the mass but are relatively coarse. A few very sparsely disseminated amygdules filled with calcite are seen throughout this member; at the basal portion the luster mottling is much less pronounced and is of smaller size where present.

476 to 486. Rock is a dark, moderately coarse grained diabase showing rather large luster mottling. Veins of calcite are particularly wanting throughout this member. This luster mottled diabase is very compact and hard as is shown by the length and character of the drill cores; some of these are at least two feet in length

and retain perfect symmetry showing very slight wearing away. This member also has a distinctly greenish cast due to the amount of finely disseminated chlorite which is present throughout it. The lower portion does not furnish as long cores and the rock does not seem to be as thoroughly massive as the upper member. The character, however, of both portions is very much the same, only the lower portion is more often cut by calcite veins. Chlorite is seen to be present on many of the vein faces and it is considerably gouged and polished as though the result of slickensiding action. The luster mottling in the central portion is not as pronounced as in the upper but it gradually merges from the upper with quite a sharp line of demarcation. By this it is not to be understood that the lower portion is not luster mottled for it is distinctly so.

486 to 496. A rock of practically the same character as the preceding, in some instances the core being cut by veins of calcite horizontally. The luster mottling is rather pronounced showing an increase over the base of the preceding member. This rock has a dark greenish color and is moderately coarse grained. Not only is this rock intersected by horizontal veins but also vertical veins cut the core. These veins are, however, relatively rare and the core furnished by this member is of good quality, sometimes a foot and a half in length. Chloritic bunches are found throughout the member but there are no distinctly large separate accumulations of this mineral. Towards the lower portion the rock ceases to show such a coarsely luster mottled character as in the upper portion and merges more into an non-poikilitic trap.

496 to 500. A reddish, moderately fine grained trap with a large amount of irregular disseminated chlorite. The chlorite also occurs in rather regular shaped amygdules of a rounded outline. This trap is very much iron stained, calcite is also present and some large bunches of amygdules of irregular form filled with calcite with an outer envelope of laumontite. This member has a distinctly decomposed appearance even in the cores here represented. Near the very bottom of this member occurs a considerable amount of epidote associated with calcite, the epidote and calcite both occurring in irregular masses throughout the core. Leading out of these various amygdules are various little bunches or veins of small extent both laterally and vertically.

503 to 506. A greenish, somewhat epidotic, amygdaloidal trap with amygdules filled with calcite and epidote. In some instances drusy cavities are filled with epidote in long projecting needle-like forms. The outline or form of these amygdules is very regular, and from the evidence presented by the core, the epidote is later than the calcite. This rock is a reddish brown in its general color and this has been changed to something of a greenish tinge by the presence of epidote. Slightly below the upper portion of this member, occurs a very dark, moderately fine grained trap, which is represented by No. 3 of this series. In this trap there are bunches of a reddish hematitic color which are probably derived from the decomposition of some of the constituent minerals. This dark trap member is represented by the cores as only a couple of inches in length and is succeeded by another portion very similar to the top of this member, namely, a reddish brown, moderately fine grained trap with numerous large irregular amygdules filled with calcite and epidote. This epidotic portion appears to be in the form of an irregular vein which cuts across the core at nearly right angles. This vein of epidote is represented by a band not exceeding three-quarters of an inch in its greatest dimension, and extremely irregular in shape so that in portions it is not over one-sixteenth of an inch in width. This epidotic portion is filled by a reddish, fine grained trap with bunches of somewhat regular outline of chlorite. The constituent minerals are not to be determined in this specimen on account of the fine grained character of the rock.

The chlorite bunches seem to be somewhat spherical in their general outline. This member also shows certain reddish iron stains throughout the mass, which are probably due to the decomposition of the iron minerals, possibly the chlorite.

506 to 511. This member starts in a somewhat reddish brown, amygdaloidal trap. The amygdules are of moderately small size, and some of them are filled with quartz. Calcite is also present, but the main part of the amygdule filling is quartz. This rock has a distinctly greenish color owing to the amount of epidote present and the core is intersected by numerous veins of calcite which intersect the core at an angle of about 45°. The amygdules grow smaller and smaller in size as we go down the series but finally we come in the central portion of this member to a greenish sand with which there is a considerable brownish material mixed. Subsequent to this sand occurs an amygdaloidal trap very rich in epidote which is disseminated throughout the ground mass, and also occurs in small drusy cavities in vesicular form. The presence of the epidote has given a distinctly greenish color to this amygdaloidal trap. In No. 7 of this series a vein of chlorite and epidote about an inch in thickness is seen to be filled with a quartz. In this connection it is interesting to note that strings of quartz proceeding from the amygdules intersect an epidote band and continue through it, thus showing that the quartz is younger than the epidote. This is well seen in fragment No. 7 of this series. The very bottom of this core is represented by an extremely rotten and much decomposed trap of a brownish iron stained color.

511 to 515. A moderately fine grained trap with considerable amount of chlorite present in irregular bunches disseminated throughout the ground mass. In some instances this chlorite has been decomposed, leaving the irons present as a reddish hematitic stain on the core. On fresh fracture it is seen that this rock is of a dark brownish gray color. Calcite is present in the form of veins cutting the core horizontally. In one vein of calcite a little prehnite is also present. The lower portion of this member consists of an amygdaloid or amygdaloidal trap in which there is a considerable amount of epidote present. The form of these amygdules is somewhat irregular but they are of relatively small size. Several of these portions are represented only by sand from the sand pump. In portions epidote is abundantly present, but in sparsely disseminated amounts.

515 to 524. A reddish brown amygdaloid with amygdules of very large size, the amygdules being filled for the most part with calcite. In some instances, however, there is a considerable amount of crystallized epidote in small cavities and in one instance at least, in No. 7 of this series there is a large quartz crystal finely crystallized in one of these drusy cavities. There is a large amount of quartz filling in some of these large irregular druses. One of these portions is represented in fragment No. 12 which has for the major part of the core a mass of quartz which is filled with irregular fragments of greenish chlorite. Irregular fragments of a reddish green amygdaloidal trap are also seen surrounded by this quartz and the whole has very much the appearance of a brecciated vein. In this quartz there are a few small crystals of copper. The contact between the quartz and the adjacent rock shows that there has been some slight alteration. The greenish trap near the quartz is seen to become more reddish and this reddish stain has somewhat permeated the quartz. Towards the lower portion of this member the rock becomes considerably more epidotic or chloritic but this gives it a much greener character. The vein material stops at about 522 and is followed by this greenish, fine grained trap with a few bands of chlorite and a few irregular disseminated amygdules filled with epidote and calcite, the calcite in this instance being older than the epidote. The very lowest member of this portion is represented by a much decomposed brownish green, much altered trap. This trap shows its extreme decomposition in the very

small comminuted fragments which are preserved in the drill record. The very end of this member is represented by a brownish sand with a few of the constituent minerals recognizable. This sand has a somewhat greenish cast due to the amount of epidote present in the rock.

524 to 526. A dark greenish trap with numerous bunches of chlorite. The whole core shows that this chlorite is present throughout the mass and in some instances it looks as though it had been dragged out and rolled by slickensiding motion into greenish striated plates.

526 to 530. The upper portion of this member consists of an amygdaloidal trap of a somewhat open textured character with considerable quartz, calcite and epidote present as filling for these irregular cavities. Veins filled with laumontite and calcite also intersect the rock horizontally; the filling of the amygdules is in very large part quartz. Below the upper portion of this member the rock becomes more of a typical trap, of a dark, nearly black color of such a relatively fine grain. that none of the constituent minerals can be recognized by the naked eye. The cores from this member are sometimes cut by horizontal veins filled with calcite. Bunches of chloritic material are present throughout the mass and appear to have a general, rather irregular outline. Near the lower portion of this member the rock becomes considerably more amygdaloidal. The upper portion of this amygdaloidal member is marked in the core by a band at least an inch thick of greenish chloritic material which is probably derived from epidote. The amygdaloid is of a greenish brown color. The filling of the amygdules is in large part quartz. Near the contact of this amygdaloid with the greenish epidotic portion the amygdaloid has a much more reddish color and along the contact between these two parts has rather irregular apophyses of the trap, including epidote. This amygdaloid has a distinctly green color due to the amount of epidote which is present in small disseminated particles throughout it. In the drusy cavities which have remained open, epidote is seen to have crystallized out into needles.

530 to 533. Much broken up drill core of a greenish brown character with some irregular amygdules of considerable size filled with quartz, much the same as the preceding, but the whole rock with a much more brownish cast than the preceding. The amygdules are scattered so widely that few appear in the drill core. The lowest portion of this member is represented by a brownish sand in which the various members can not be determined. From about 496 up to this point the cores have all been very much broken up and the fragments rarely exceed an inch in length showing the generally decomposed fractured character of the beds which this series represents.

533 to 542. The upper portion of this member consists of a dark brownish, moderately fine grained trap with a considerable amount of chlorite in moderately large sized bunches scattered throughout the core. This chlorite is in rather disseminated, irregular bunches but further down it appears in rather greater quantities in rather spheroidal forms. Calcite is sometimes present also as a filling in these chloritic bunches and in all such cases it appears as though the calcite were formed previous to the chlorite. In many instances the chlorite has been decomposed and altered into a reddish iron material and a few seams of calcite cut the core at an angle of about 45° and in some instances the original filling of calcite has been apparently largely replaced by chlorite. In certain instances the chlorite of this trap appears to have suffered slickensiding. At the very bottom of this member the color of the trap is somewhat darker and there is a slight tendency towards rather small luster mottling.

542 to 552. The upper portion of this member consists of a dark, very fine grained trap, much the same as the preceding, the luster mottling, however, not being as

evident and bunches of chlorite are somewhat less frequent also. The core is intersected by veins filled with calcite and laumontite which intersect it both horizontally and vertically. The core preserved from this series is of good quality and of moderate length. Towards the central portion of this member the fine luster mottling again appears to some extent, and a few bunches filled with calcite are also evident through the core. The luster mottling here represented seems rather to be a localized feature, but it does not extend throughout very much of the core. Slightly below the central portion of this section the rock becomes distinctly more greenish and begins to lose the luster mottling which characterized it in the central portion. Together with this change the trap becomes somewhat more amygdaloidal, the amygdules being of rather regular outline. The filling of the amygdules has been, for the most part, of calcite but in some instances chlorite is also found as a filling. It is highly probable that this chlorite was derived from the epidote which is sparingly represented in these cores. The amygdules are of very small size and rather widely disseminated throughout the specimen. This amygdaloidal portion is rather localized but it does not extend much more than six or seven inches as represented by the core. Below it comes a more fine grained, homogeneous trap of a reddish brown color which is filled by a more reddish colored amygdaloid. The filling for this amygdaloid is calcite and epidote. The epidote has been altered to chlorite. This phase is well represented by No. 20. Following this portion of the member the rock becomes more greenish as represented by No. 23 and owes its character to the amount of epidote present. This portion lies near the base of this member. Epidote is present in considerable amounts, apparently as a vein. This epidote is rather drusy and contains numerous cavities in which crystals of great beauty project. The width of this vein, judging by the core is perhaps eight inches. This is followed by a much decomposed and broken up, dark greenish, amygdaloidal trap. The amygdules in this case are filled with quartz which has a somewhat pinkish color. The amygdules are rather irregular in outline. This portion of the core is retained in only small comminuted fragments.

525 to 555. This portion consists of an amygdaloidal trap, the amygdules being sparingly preserved in the core. The amygdules are, for the most part, filled with quartz which has a more pinkish color as before noted in the preceding member. The ground mass in which these amygdules occur is a dark, moderately fine grained trap in which few of the constituent minerals are to be recognized.

Central drill hole 2. 488 feet deep, dip 60°, elevation 61 feet above datum and horizontally 6472 feet, to which may be added (cot 24° x 123) for the difference in elevation, in a direction S. 18°E., from an outcrop of the Allouez conglomerate at an elevation of 184 feet,—840 feet from Hole 1. Hubbard makes the strike of the Kearsarge conglomerate N. 80° 11′ E. in the Central mine and its dip 21° to 27°. The uncertainty of the strike may make 1% difference in horizontal distance. The Kearsarge is about 2599′ below the Allouez in the Central mine. The top of the hole is about 6747 x sin 24°=2740 feet below the Allouez.

Central drill hole 8. (Cend. 8). A vertical hole 727 feet deep should be comparable with Cend. 1, faults apart, for it is distant from it 170 feet along the strike line S. 72° W. and 13 feet N. 18° W. from the strike line. Accordingly it should be 827 across the strike below, and 26′ vertically below 2. Its elevation is probably about 35′ above datum and 11 feet below No. 1. By barometer from Keweenaw Central

R. R. 1175 A. T. Its top should have struck the horizon of Cend. 1, had they neither had any overburden, if the strike is correctly assumed and there are no faults. But as Hole 8 is vertical, to get the equivalent thickness of strata one must multiply the vertical distance by the cosine of the dip making them between 8/10 and 9/10 of the present value. If we take the average dip of sediments and contacts in connection in the drill hole, the dip indicated is 29°, which is in very fair harmony with dips otherwise assumed. The next drill hole south No. 5,[1] seems to have dips of about 35°. On the other hand there is nothing in Cend. 1 to correspond to Cend. 8. 42-319 which can not well be less than 277 x cos 29°+20=260 feet deep by direct measurements, confirmed by the coarseness of grain. This same big ophite should also appear in the bottom of Cend. 2. The only chance for it is to suppose that it is the Bed 58, just entered (Cend. 2 442-498) and correlate Cend. 2. 457 with Cend. 8 42 implying a dip of 31°½ which we shall do.

Overburden 42, then bed rock. This is right in the swamp.

(58 bis) Ophite. (250)

Trap 8.42-314'9"=273+ (235+15)

The amygdaloid top is not present. The mottling is well marked as follows:

mm.	2–3,	7?,	5–7?,	12?,	9,	5,	3,	2–3,
depths in hole	42,	44,	60,	172,	202,	218,	239,	273,
or distances of	240,	238,	223,	124,	98,	84,	66,	36,
mm.	2,	1–2,	1					
depths in hole	279,	295,	305,	314'9"				
or distances of	31,	17,	8,	0ft.				

from the bottom if the dip is 29° or so. This is a well-marked ophite and has a nearly normal increase in grain and does not appear extra feldspathic. At 60 there seems to be dark resinous grains of porphyritic augite; at 66-8 feet there is a vein of prehnite and copper making an angle of about 34° with the drill core, perhaps therefore nearly at right angles to the bedding and thereafter it is very chloritic, as if near a big slip. The feldspars are small and the general effect dark. Another chlorite seam at 282.

This would appear to belong close under the Wolverine sandstone. At the Wolverine the second belt below, from 87-307 feet in the 11th level cross-cut, is a heavy belt of trap, say 145 feet thick.

Base below base of Wolverine sandstone (281)

59. Melaphyre (30) (311)

Scoriaceous amygdaloid d 8. 314-331=17 (15)

This amygdaloid is badly broken up and mixed with red clasolite and epidotic sandstone, and may represent a sedimentary belt as well as the top of the ophite below, dip apparently 35°

Trap d 8. 331-348=17 (15)

A fine grained melaphyre with epidote and amygdaloid inclusion at 337-338, broken up from 344 down. It is noticeable also that scoriaceous amygdaloids, and an abundance of epidote, and red sediments are associated with the beds beneath the Wolverine sandstone, also at the Wolverine (amygdaloid and epidote) and at the Arcadian (bottom of Hole 2 and Hole 19), and on the Calumet and Hecla property A, 2-21, 1-21, B. Cf. also Franklin Junior 1, 2, 3, and the

[1] Holes 1 and 2 were sent to the Geological Survey office to examine. Then where drilling was recommenced the numbering of the boxes seem to have begun with 1 again, 1, 2, 3, 4, A, 5, and then the last hole was numbered 8 as may be easily verified by comparing depths.

more massive parts of the flows are more feldspathic, sometimes doleritic, sometimes glomeroporphyritic, when ophitic faintly so, the mottling not showing until it is quite coarse.

60. Chocolate sandstone. Dip 26. 5°, clasolite? at d 8. 348 (311)
Cf. C. & H. B. 463.

61. Amygdaloid d 8. 348-350=2 (2) (12)
Trap reddish, fine grained with a few chloritic amygdules-360=12

(323)

62. Felspathic melaphyre (35) (358)

Amygdaloid d 8. 360-371=11 (11)
Marked red, granular with white amygdules; perhaps only a band in the flow above to 369, then coarser feldspathic with a few large amygdules and at 371 epidote.
Trap growing coarser then finer d 8.-400 29 (25)
Dip of bottom contact 17°

63. Melaphyre (8) (364)
Amygdaloid d 8. 400-404=4 (3)
Trap growing finer d 8. 404-410=(5)

64. Feldspathic melaphyre (40) (404)

Amygdaloid d 8. 410-8.420=10 (8)
Epidote seam, amygdaloid with chlorite and calcite, and amygdaloid with a little red clasolite matter and prehnite.
Trap d 8. 420-459=39 (32)
Coarsest, somewhat mottled about 447.

65. Amygdaloid (10) d 8. 459-462=3 (2) (414)

Poor, coarse.
Trap somewhat amygdaloidal d 8. 462-471 (9)

66. Ophite, feldspathic. (12)

Amygdaloid d 8. 471-477=6 (5) (426)
Red with white amygdules, and epidote and calcite seams.
Trap d 8. 477-485=8 (7)
Faintly mottled.

67. Ophite, feldspathic. (23) (449)

Amygdaloid d 8. 485-491=6 (5)
Red, marked with small amygdules of epidote, chlorite and some calcite.
Trap d 8. 491-512=21 (17)
There are seams making an angle with the hole, (the vertical), of 29° and perhaps about at right angles to the dip. There is a faint 2-3 mm. mottling at 501, growing finer below. The dip of the bottom contact is between 26° and 45°.

68. Amygdaloid d 8. 512-514=4 (42) (2) (452)

Marked with pink amygdules.
Trap d 8. 514-516=2 (2)

69. Ophite, feldspathic. (11) (463)

Amygdaloid d 8. 516-518=2 (2)

Marked like the one above.
Trap d 8. 518-528=10 (9)
70. (9) (472)

Amygdaloid d 8. 528-532=4 (3½)
Poor.
Trap (with chloritic amygdules) d 8. 532-538=6 (5)
71. Feldspathic ophite (13) (485)

Amygdaloid d 8. 538-544=6 (5)
Red, fine grained chlorite-540, then 1 inch of epidote, and feldspathic, chloritic, somewhat amygdaloid-544.
Trap d 8. 544-553=9 (8) (13)
72. Ophite (122) (607)
Amygdaloid d 8. 553-556+=3 (3)
Red marked to 556, coarse a few feet farther and fine grained to 565.
Trap d 8. 556-693=137 (189) (122)
Grows coarser to about 644, as follows:

mottles	2 mm.,	3 mm.,	3-5 mm.,	5 mm.,	3 mm.,	2 mm., at
depths	576,	583,	599,	627,	666,	675,
distances	103,	96,	82,	58,	23,	7, from the foot.

At 583 there are chloritic seams and from 682-685 one of epidote.
(73 and 74 see Hole 5) (25) (632)

Amygdaloid d 8. 693-702=9 (8)
Red, fine grained with chlorite and epidote, from 695-702 very epidotic.
Trap d 8. 702-722=20 (17) 25
Coarse, feldspathic, growing finer to 722, the top of the contact being about 26°,—an epidote seam at 712
75. Amygdaloid d 8. 722-726=4=Cend. 5.8 8 (637)
Trap, feldspathic d 8. 726-727+1

Central drill hole 5. 950 feet from No. 8 in a direction S. 18°E. Elevation by barometer 195 A. T. Vertical depth 818 feet. The boxes at the mine are labelled 3. Dip about 35°. At this dip the bottom of 8 should be equivalent to 92 feet down in No. 5, and in turn its bottom should be equivalent to 185 feet down in No. 3. The correlation of 8 d 5. 807-816 with d 5. 182-186 is a fair one, and we may also compare d 8. 722-727 with d 5. 88-92.

The sediment d 5. 98 to 100 does not appear in 8, nor does the ophite which appears in 8 down to 693 appear in 5. This gives us a 33 foot range of correlation and the 34 feet beds between are small amygdaloids upon which we cannot depend.

Overburden sand 65 feet.
(73) Amygdaloid with white amygdules d 5. 565-68 3 (2)
Feldspathic melaphyre d 5. 568-84 10 (12) 14
With chloritic amygdules.
Contact at the base dips at angle of 7 or 8:10 (about 36°?)

(74) Amygdaloid
White with epidote seams d 5. 584-86 2 (2)
Trap d 5. 86-88 2 (2) (3)
Probably a gush of the underlying flow

Below the base of the Wolverine sandstone (631)
Glomeroporphyritic.

(75) Amygdaloid
White with epidote seams d 5. 88-92=4 (3+)=[8.722] 639
Trap d 5. 92-98 (6) (4-½) (8)
A feldspathic melaphyre with chlorite amygdules.

76. Sediment d 5. 98-100 2 (2) (641)
Aphanitic, mottled pink and green like castile soap, epidotic, dip 35°.
Base of this sediment below the Wolverine sandstone No. 9.

77. Amygdaloid d 5. 100-102=2 (2) (31) (672)
Feldspathic melaphyre d 5. 102-138=36 (29)

78. Inclusion bed, feldspathic melaphyre (820)
Amygdaloid d 5. 138-141=3 (2)
Trap d 5. 141-320=179 (146) (149)

Faintly mottled with amygdaloid inclusions, and slightly doleritic at 169, 175, 183, 189. At 201.6 the feldspar is 4 mm. long. At 223 there is a vein of porcelainic datolite. At 267, 277, 285, 289, there are marked inclusions of epidote amygdaloid. From 313 to 318 are marked clay veins dipping from 31° to 38° with brecciation.
Cf. Arc. Belt 74.

79. Feldspathic ophite. (999)
Amygdaloid d 5. 320-335=15 (19)
Calcite poor.
Trap d 5. 335-540=205 (167)
Feldspathic, fine grained, faintly mottled to 367, quartz calcite seams to 366 and at 419, mottled 4 mm. across at 450, 3-5 mm. at 499, at 501 laumontite seams.

80. Feldspathic melaphyre. (1035)
Amygdaloid d 5. 540-544=4 (3)
At first small amygdules and then coarser structure.
Trap feldspathic d 5. 544-585=41 (33)
There is an amygdaloid inclusion at 564.

81. Conglomerate and sandstone d 5. 585-593=8 (7) (1042)
A red sandstone at the base basic, giving a number of good chances to measure the dip, which average (8 measurements) 70 per 100.
Cf. Arc. bed 76.

82. Melaphyre d 5. 593-632=39 (32) (1074)
Amygdaloidal somewhat throughout, fine grained.

83. Feldspathic malaphyre (20) (1094)
Amygdaloid d 5. 632-640=8 (6)
Trap d 5. 640-657=17 (14)

84. Feldspathic melaphyre (14) (1108)
Amygdaloid d 5. 657-662=5 (4)
Trap d 5. 662-674=12 (10)
Seamed at 668.

85. Feldspathic melaphyre (15) (1123)

Amygdaloid d 5. 674-685=11 (9)
Trap d 5. 685-692=7 (6)

86. Feldspathic melaphyre (29) (1152)

Amygdaloid d 5. 692-708=16 (13)
Epidotic with white amygdules on gray ground.
Trap d 5. 708-728=20 (16)
Amygdaloid inclusion d 5. 713-715
Cf. d 3. 61-128? which is also a feldspathic melaphyre. The three flows ? above appear in d 3. 61-128 as one?

87. Feldspathic melaphyre with inclusions. 64 (1216)

Amygdaloid d 5. 728-743=15 (12)
Trap d 5. 743-807=64 (52)
Faint mottling, at 758 and 767 amygdaloid inclusions, at 778 faint 1-2 mm. mottles growing finer.
In Cd. 3 we have from d 3. 128-182=54 (45) a feldspathic melaphyre, with a red and white, then greenish gray, and gray and white, with pink prehnite, amygdaloid, with an amygdaloid streak d 3. 142, then a feldspathic melaphyre with large amygdules of pink prehnite and a little copper to d 3. 182.
Amygdaloid d 5. 807-816 is we assume = d 3. 182-192

Central mine drill hole 3. 940 feet from No. 5 in a direction S. 18° E. About 922 feet across the strike. Elevation by barometer 1223 A. T. Vertical depth 708 feet. Dip by correlation with drill hole 4 33° ¾ leading to a reduction of .83 for thickness. This is making d 3. 608-612 equivalent to d 4. 67-68, a sedimentary belt characterized by an unusually fine grained, not augitic set of flows beneath. The only indication of dip in the hole itself is an amygdaloid flow contact at about 371 feet which seems to dip about 31°.

Surface d 3. 0-12.
(82. bis) Feldspathic melaphyre d 3. 12-37=24+ (20)
(83. bis) Feldspathic amygdaloidal melaphyre.
Amygdaloid d 3. 37-54=17 (14)
The feldspars are 1 to 2 mm. broad, larger than usual, but uniform, not glomeroporphyritic, more doleritic in type, a coarse laumontitic amygdaloid.
Trap d 3. 54-61=7 (6) (20)
Finer grained.
(84-86. bis) Feldspathic melaphyre.
Amygdaloid d 3. 61-70?=9 (7)
At first amygdaloid, then fine grained, marbled, epidotic.
Trap d 3.70-3.128=58 (47) (54)

Dark, dense, epidotic at 75, grows coarser at least to d 3. 100, a feldspathic melaphyre.

87. Feldspathic melaphyre.
Amygdaloid d 3. 128-138 10 (8)
Trap d 3. 138-182 44 (36) (44)

Amygdaloid streak also at 142, pink prehnite and copper are characteristic

Below the base of the Wolverine sandstone according to the correlation used (1216)

88. Feldspathic melaphyre (1263)

Amygdaloid d 3. 182-192=10 (8+)

Trap d 3. 192-239=47 (38+) (47)

Greenish, hard to 186, poor to 192, at 194′ 9″ crystals in cavities, apophyllite, stilbite, etc., doleritic at 198, at 234 green epidote inclusion.

89. Melaphyre (9) (1272)

Amygdaloid d 3. 239-244=5 (4)

Trap d 3. 244-250=6 (5)

90. Feldspathic melaphyre (5) (1277)

Amygdaloid d 3. 250-252=2 (2)

With prehnite quartz and copper at 251′ 3″

Trap d 3. 252-256=4 (5)

91. Melaphyre (9) (1286)

Amygdaloid d 3. 256-258=2 (2)

Gray, rather coarse

Trap d 3. 258-267=9 (7)

92. Melaphyre amygdaloidal (11) (1297)

Amygdaloid d 3. 267-278=11 (9)

Greenish gray

Trap d 3. 278-280=2 (2)

93. Feldspathic melaphyre (74) (1372)

Amygdaloid d 3. 280-285=5 (4)

Trap d 3. 285-371=86 (70)

Marked contact at top and a red amygdaloid passing into a coarse gray one and then a feldspathic trap, with 3 mm. mottles at 344?, and epidote at 369-370.

The dip of contact is 31°.

94. Feldspathic ophite. (182) (1554)

Amygdaloid d 3. 371-374=3 (2)

Brown with numerous amygdules of pink prehnite.

Trap d 3. 374-595=221 (179)

Generally massive feldspathic, with occasional coarse amygdules of chlorite or prehnite, doleritic at 405. Faintly ophitic, 7 mm. across at 440-464; from 511-521 a seam nearly parallel to the drill of prehnite, quartz, chlorite; at 528 an epidotic inclusion.

95. Feldspathic melaphyre (19) (1573)

d 3. 595-608=d 4. 40-67? 23

From d 3. 595-599 is an ophitic bed, mottled pink and green like castile soap, passing into a plain glomeroporphyrite; from 599 to 604 is plainly a glomeroporphyrite; at 604-6 is like 595-9; then it relapses into glomeroporphyrite once more-608.

96. Conglomerate. Cf. Old Colony sandstone
d 3. 608-612=d 4. 67-68=5 or (4) (1577)

Fine grained, basic, but quite distinctly a sediment. This would be somewhere about 1600 feet below 9. Cf. Arcadian Belt 76 which is 968 below the Wolverine sandstone, and only 12 belts. The association with feldspathic doleritic ophites, often slightly and coarsely amygdaloid with prehnite is similar.

Central mine drill hole 4. 850 feet from No. 3 in a direction S. 10° E. About 840 feet across the strike. Elevation by barometer 1245 A. T. Vertical depth 675 feet. Dip by correlation with drill hole 3, 33° ¾. According to this dip the top of 6 should be = d 4. 540 and d 6. 39 should be d 4. 579. As a matter of fact the glomeroporphyritic character and fine grain of the flows are notable points of resemblance, but the nearest comparison of their tops must be d 6. 39=d 4. 501 to 517 or 648 or 675+ which gives dips respectively of 30° to 30° ¾ or 37°. From a comparison of 6 and 6A we get (as we shall see) a dip of about 36° which indicates that the correlation d 6. 39=d 4. 648 is the more likely, in which case the factor to reduce to true thickness would be .81 instead of .83 for 33° ¾.

Overburden to ledge 40 feet.
Feldspathic faulted ophite 40-67
Sandstone and brecciated amygdaloid 67-68′ 3″.
Base below Wolverine sandstone (1577)

97. Porphyrite? (80) (1657)

Amygdaloid	d 4.	68-69=1	(1)
Trap	d 4.	69-167=98	(79)

The amygdaloid is poor and the trap uniform and fine grained.

98. Porphyrite? (115) (1772)

Amygdaloid	d 4.	167-170=3	(3)
Trap	d 4.	170-309=139	(113)

The amygdaloid is greenish, poor, but with a little copper, a hard white amygdaloid with prehnite and datolite. The feldspar is fine grained and feldspathic, a little darker and coarser toward 221. There is a chloritic seam crossing at an angle of 11° ⅓ with the drill core, i. e., perhaps dipping 79° from the horizontal about 4.267′.

99. Glomeroporphyrite feldspathic (87) (1859)

Amygdaloid	d 4.	309-314=5	(4)
Trap	d 4.	314-417=103	(83)

A glomeroporphyritic amygdaloid with calcite, prehnite and a trace of copper, then fine grained and porphyritic, at d 4. 354 amygdaloid bomb with speck of copper.

100. Glomeroporphyrite (68) (1927)

Amygdaloid	d 4.	417-428=11	(9)
Trap	d 4.	428-501=73	(59)

A red glomeroporphyritic amygdaloid, somewhat brecciated, epidotic, with an epidote seam directly under from d 4. 431 to 433, then at 447 a faint 2 mm. mottling, yet not plainly ophitic or due to the augite, of the same type as above and below.

101. Glomeroporphyrite (145)? (2072)

Amygdaloid d 4. 501-508 or 514?=13 (11)
Trap d 4. 514-675+161?=132+

Begins as a characteristic red glomeroporphyrite, amygdaloid in streaks, a coarse, more pronounced glomeroporphyrite (2 mm.) from d 4. 508 to 511, then finer to 514, then a solid, light colored feldspathic melaphyre, with chlorite amygdules the rest of the way; at 585 there is a prehnite chlorite seam, and another at 536 with a little copper, and at 648 an amygdaloidal streak and yet it is neither ophitic nor doleritic in spite of its thickness, but of a well-marked type, toward which the beds at the bottom of 3 also tend and those in 6 and 6A.

Central mine drill hole 6. 845 feet from No. 4 in a direction S 10° E. or about 835 feet across the strike? Elevation by barometer 1260 feet. Vertical depth 801 feet. Dip by correlation with 6A which starts from the same point at a dip of 64° .5 calling d 6A. 290=d 6. 352 is 35°⅓. The reduction factor to get thickness will accordingly be .81. Correlating with Hole 7, the top of it should be equivalent to d 6. 610. The nearest correlation we can get to this is d 6. 650-801, a coarse feldspathic and ophitic doleritic flow, with d 7. 37-257. The grain at the bottom of 6, 10 mm., would indicate that the bottom would be at d 6. 950 or some such point, but the grain at d 7. 37 indicates that the top of the flow is not much above, perhaps corresponding to d 7. 0. It seems likely that this rather unusually large flow is correctly correlated and comparing d 7. 0 with d 6. 650 and d 7. 257 with d 6. 950 we get a dip of 36° ¾ to 38° ⅓, which agrees well enough with a progressively increasing dip to the South.

Overburden 33 feet

We probably make no large error in assuming d 6. 39=Cend. d 4. 675+ or below the Wolverine (2072)

Begins in a fine grained trap with small chloritic dots.

102. Glomeroporphyrite (37) (2109)

Amygdaloid d 6. 39
Trap d 6. -85

Begins with small pink feldspar phenocrysts 1 mm. long, appears coarse at 44, then at 54 finer and from 60-73 a fine dense trap, then glomeroporphyritic from 73-85, but the flow boundary is very doubtful.

103. Glomeroporphyrite. (44) (2153)

Amygdaloid d 6. 85-87=2 (2)
Trap d 6. 87-140=53 (43)

The general habit along here is that of the porphyrites and Ashbed group. From d 6. 85-87 is amygdaloid with empty or chloritic amygdules, then light greenish gray and from 101 on very faintly mottled. At 113 it is typically feldspathic with chloritic spots, and then grows finer.

d 6. 39-140 (82 feet) correspond to 6A. 36-112 (75) feet.

104 & 105. Glomeroporphyrite (62) (2215)

Amygdaloid d 6. 140-145=5 (4)
Amygdaloidal trap d 6. 145-217=72 (58)

This begins red glomeroporphyritic with chloritic amygdules, becomes coarsely amygdaloid and feldspathic to 160. A calcite seam at an angle of 42° with the core (perhaps nearly perpendicular to the dip) crosses at 171. Toward the bottom it becomes a little darker and faintly mottled, but the feldspar laths remain conspicuous, being 2-3 mm. long at 205. This belt d 6. 140-217 (64) corresponds to 6A. 112-171? (58). The heavy bottom belt of trap is well marked and characteristic, the top is amygdaloidal and we see in comparing the two holes the irregularities of flow in the amygdaloids.

106. Glomeroporphyrite (110) (2325)

Amygdaloid d 6. 217-220=3 (3)
Trap d 6. 220-352=132 (107)

The amygdaloid is red, glomeroporphyritic with chlorite and some calcite amygdules, then remains fine grained down to 273 when a faint mottling begins. At 278, 304, 315 there is a somewhat doleritic texture. From 2 mm. at 339 the mottling gets finer (at 341 1 to 2 mm.) to the bottom.

This d 6. 217-352 (122) agrees with d 6A. 171-290 (117) both in the thickness and the general glomeroporphyritic character and fine grain with an ophitic tendency toward the base only about 20 feet above it. This is not so pronounced a glomeroporphyrite as the beds above it.

107. Glomeroporphyritic feldspathic ophite. (157) (2482)

Amygdaloid d 6. 352-357=5 (4)
Trap d 6. 357-544=187 (153)

In this flow although it begins with a glomeroporphyritic amygdaloid and remains fine grained and feldspathic to 367, there is a much plainer ophitic mottling, beginning from 390-304; at 406, 451, 454, 496? feet we appear to have mottles
(116), (78), (76), (40)
4-5, 4, 5-7, 3
mm. across, being plainer than anything above in Hole 6 or 5. From 376.9-379.9 there is a well-marked vein of prehnite with copper; at 397-400 it is doleritic with feldspar laths 5 x 1 mm; at 406′ 5″ there is a vein with datolite crystals; at 413 it is doleritic; at 415 there is a speck of copper, at 425 there is datolite. The base is uniform. Correlating d 6. 413 with 6A. 339 we have a dip of about 36° ½.

108. Glomeroporphyrite? (9) (2491)

Amygdaloid d 6. 544-552=8 (6)
Trap d 6. 552-555=3 (3)

This is a poor red amygdaloid and the belt probably belongs with the one above or below.

109. Glomeroporphyrite. (4) (2495)

Amygdaloid	d 6.	555-558=3	(3)
Trap	d 6.	558-560=2	(2)

The amygdaloid is red glomeroporphyritic, the trap coarse, feldspathic, with chloritic dots.

110. Glomeroporphyrite (8) (2503)

Amygdaloid	d 6.	560-563 (or 6?)=3	(3)
Trap	d 6.	563-570=7	(6)

The amygdaloid is a brecciated glomeroporphyrite with chlorite amygdules to 563, and remains fine grained and somewhat amygdaloid to 566, then feldspathic, with the feldspar 1 to 2 mm. long.

111. Glomeroporphyrite (65) (2567)

Amygdaloid	d 6.	570-572=2	(2)
Trap	d 6.	572-650=78	(63)

Amygdaloids like these above, then a feldspathic melaphyre, coarsest (one feldspar 3 to 4 mm. x 1 mm.) from 614 to 641, at times red, toward the base finer and glomeroporphyritic.

112. Glomeroporphyritic ophite (205)+? (2772)

Amygdaloid	d 6.	650-665=15	(12)	
Trap	d 6.	665-801′ 3″=136+	(110)	122+

Amygdaloid glomeroporphyritic-653 passing into coarse chloritic; the trap beginning grayish green feldspathic gradually becoming mottled and ophitic, at

677, 685, 700, 731, 801′ 3. the mottles are
2, 3, 4, 5+, 10 mm. across; doleritic at 687-9.

The grain being as coarse at the bottom as elsewhere we should infer at least as much more, were it not that in these feldspathic and glomeroporphyritic ophites the coarsest mottling is generally much nearer the base. The thickness according to the usual formula for augite mottling would be still more than 140-+16 from the bottom of the hole (180′ below it), so that the total thickness would be more than 262-+16 feet in all.

Now Hole 7 is 900 feet, or 890 feet perhaps at right angles to the strike from No. 6, and 20 feet higher so that the bottom of d 6. 801 at a dip of 36° 10″ would correspond to d 7. 171. It is therefore to be expected that this heavy ophite should appear at the top of it, and we do indeed find that it begins under the drift at 37 feet with a doleritic streak and a coarseness of 2-3 mm. and that the same belt continues to d 7. 257′ 6″, being coarsest near 155 feet. Taking grain and all into account it seems as though the doleritic streak d 6. 687 might be at the same level as that at d 7. 37 which would imply a dip of 37°. In such case the top of the flow should have come at 70, and the bottom at d 6. 907. It is possible that my estimate of the grain at 801 feet was somewhat exaggerated.

Central mine drill hole 6A. From the same station as 6 but only 414 feet deep and at an angle of 64.5° so as to cut the beds more nearly at right angles, really at about 80°, so that the reduction factor is about .985.

Overburden 36 feet.

(102. bis) Glomeroporphyrite. (20)

Amygdaloid d 6 A. 36-41=5 (5)

Trap d 6 A. 41-56?=15 (15)

(103. bis) Glomeroporphyrite (51)

Amygdaloid d 6 A.? 56-62=6 (6)

Amygdaloidal trap d 6 A. 62-112=50 (49)

From 56-62 prehnite, calcite, epidote, etc., and a little *copper*, and, I suspect, a contact. Thence to 70 is a marked glomeroporphyrite with chlorite amygdules; these occasional coarse hard amygdules of prehnite and *copper* continue to 87 and beyond. The top of the flow is very uncertain, and very probably the two are really one, the finer part being merely a flowage streak.

(104. bis) Amygdaloid d 6 A. 112-117=5 (5)

Amygdaloidal trap d 6 A. 117-127=10 (10)

White amygdaloid with radiated greenish prehnite on a red ground and *copper* (at 114) passing gradually into chloritic amygdaloid forms into which the feldspar laths may be seen to project. At 117′ 6″ the general color tone is light gray-green with white feldspar laths on a reddish ground and radiated chlorite. One fine grained amygdule of radiant chlorite fibres has an epidote center. At 122 rock becomes seamed, red, hard.

(105. bis) Glomeroporphyrite

Amygdaloid d 6 A. 127-130=3 (3)

Amygdaloidal trap d 6 A. 130-171?=41 (40)

The amygdaloid at 127 contains some copper, and also flesh colored crystals of a greasy luster, and coarse chloritic amygdules continue at least to a seam at 138 of calcite and pink feldspar (?) making an angle of 17°.5 with the hole. Comparing this with the fissure crossed at 171 in 6 making an angle of 42° we find that they cannot be made to agree closely at all and that if the seam is at all the same it is irregular so that the angle at which it cuts the hole has not much meaning. Still it must be in a general way not far from normal to the dip.

Below is a fine grained trap.

(106. bis) Amygdaloid d 6 A. 171-179 (8)

Trap d 6 A. 179-215-220 Fault?-290 (109)

The amygdaloid is brecciated, i. e., shattered, with quartz, epidote, etc., and below it is seamed but plainly getting coarser. At 195 it is somewhat amygdaloid and chloritic,- a bomb-like inclusion. At 200 there is a red streak. At 210 it is rather dark, and a mottling appears (2 mm?)

From 215-220 it is seamed and of a different appearance but not amygdaloid and seems to get coarser to 268, remaining dark, fine grained, faintly ophitic, then gets finer so that at 276 the mottling is 1 to 2 mm.

(107. bis) Glomeroporphyritic ophite. (122+)

Amygdaloid d 6 A. 290-298 (8)

Trap d 6 A. 293-414+ (114)+

The amygdaloid is red and white, the trap cut with seams of datolite nearly parallel to the hole. At 310 feet the mottling appears (2-3 mm.); at 387 it is 5 mm.? and the rock continues coarse to the end; at 339 it is doleritic, the same streak as d 6. 413? (implying a dip of 36° 10′).

Central mine drill hole 7. 900 feet from No. 6 in a direction S 10° E or about 890 feet across the strike? Elevation by barometer 1280 feet, and the land is a little higher 1285 feet A. T. between this and No. 6. Dip by correlation with No. 6, 37°. Reduction factor to get the thickness will accordingly be .795.

"Overburden to ledge" d 7. 0-36.

112. Feldspathic ophite d 6. 650-801′3″+=d 7. 36-257.6

36-37 is doleritic with feldspar 2-3 mm. long and chloritic interstices very plain; at 43, 1 to 2 mm; at 41, epidote; from 46 to 48, 51′ 6″-55 and 79-81 are streaks of chloritic amygdaloid, probably inclusions; at 62 it is very light colored, and on the whole it is faintly mottled and feldspathic. The mottling is:

43,	70,	75,	94,	127,	155,	233
(168),	(147),	(143),	(128),	(109),	(41),	(11)
1–2,	3,	4–5,	5,	6,	7,	1–2

Comparing this grain as a whole with that at the bottom of 6 would indicate that the top of the flow was really near d 7. 30 and diminish its thickness to 190 feet, while at the same time they would indicate that the base in 6 was only 60 feet or more below 801, the rate of decrease being exceptionally fast, making it only 180 feet.

Base assumed below Wolverine sandstone (2772)

113. Ophite (203) (2975)

Amygdaloid d 7. 257′ 6″-267 or 276=19 (15)

Trap d 7. 276-514=238 (187)

Begins with a well-marked red amygdaloid with small white and epidotic amygdules to 267, then but slightly amygdaloid fine grained and porphyritic with occasional small feldspar crystals, to 273.

Then a poor amygdaloid (possibly having a definite contact, but probably a mere streak) to 276. Then feldspathic, chloritic and somewhat amygdaloidal nearly to 290, when the ophitic mottling begins in a dark resinous trap as follows:

at 310,	327,	343,	410,	427,	465,	483,	498,	514	
(160),	(147),	(135),	(82),	(68),	(38),	(24),	(12) feet		
2,	4–5,	5–7,	7,	10,	5–7,	3–5,	2,	mm.	contact

The increase from the bottom seems to be unusually rapid 1 mm. in 7 feet.

The trap is very dense and fine just above this contact which is well marked with a dip of 6 or 7 to 10, i. e., 31° to 35°, while some chlorite seams at 399 with some interesting red amygdules dip 28 to 10, 19° ¾ from the vertical.

114. Glomeroporphyrite? melaphyre (29) (3003)

Amygdaloid d 7. 514-520= 6 (5)

Amygdaloidal trap d 7. 520-549=29 (23)

Begins with a red amygdaloid with small calcite and epidote amyg-

dules, then at 520 becomes feldspathic almost glomeroporphyritic (cf. these glomeroporphyritic flows with those up Isle Royale and Huron streets south of Houghton) with occasional epidote calcite amygdule spots, and at 549 quite epidotic amygdaloid.

115. Amygdaloid d 7. 549-550=1 (1) (11) (3014)

Amygdaloidal trap d 7. 550-563=13 (10)

Red with chlorite amygdules (base of previous flow?) changes to yellowish green with large coarse amygdules of epidote, calcite and quartz -554 then begins to get red again and brecciated and slightly amygdaloid, then light yellow to 563. We have along here apparently a number of gushes.

116. Doleritic ophite (270)+ (3284+)

Amygdaloid d 7. 563-567=4 (4)

Trap d 7. 567-818+ (at least 100 feet probably)=251+

Begins with a well-marked red amygdaloid with quartz and epidote amygdules to 567, then massive yellowish, fine grained to 570, then reddish, fine grained to 604 where it begins to be faintly mottled; the red bed above seems quite characteristic. Dolerite streaks are numerous below and characteristic, at 648-652 (feldspar 6-8 mm. long) at 658, 660, 662, 668, 674-677, 691, 703, 710-776, and 804-818 (feldspar 10 mm. long and 2 or 3 broad, and augite 10 mm. across.)

The augite mottling is as follows:

at	604,	615,	623,	635,	645,	679,	804-818
begins		1-2,	2-3,	4-5,	5,	10,	10? mm.

The end of the section then appears to be about 3174 feet below the Wolverine sandstone in a series of large heavy ophites, which remind one of ophites at the lower part of the Arcadian section, but without the scoriaceous brecciated amygdaloid tops which there appear.

This Copper Falls-Central section gives as good a chance as any to get the thicknesses of some of the important groups rigorously.

The Lake Shore traps are		(200)
The Great (Copper Harbor) conglomerate, 4700 feet broad is perhaps		(2200)
The Eagle River group, Marvine's (c) to 45 through 44 (some cut out by a fault?) Marvine gives 1417		(1150)
The Ashbed group b. from 66 through 44 (Marvine 618)	(560)	
a. from the "diorite" (Marvine 925) or the Mesnard epidote to the Ashbed	(1020)	(1580)
The Central group from the Mesnard epidote to the Allouez slide (nearly equivalent to the Diorite group, Marvine) (1193+ 87+)?	(1324)	
from Allouez 15 to Wolverine sandstone No. 9	(3442)	
Balance in Central section	(3284)	
Estimate to Bohemia conglomerate 8	(200)	
Total Central group		(8250)
There is something like a mile of Bohemia Range group below at a steep angle		(5000)
Total Lower Keweenawan		(18,380)

My impression is that this is an under-estimate and that several hundred feet have been cut out by slide faults.

§7. EAGLE RIVER-CLIFF (FIGS. 34 AND 35.)

This is historically an important section, since the Eagle River gives the best and most continuous natural section and was thus used by Marvine in Volume I as his type section. We therefore continually refer to it and do not hestitate to refigure it with some slight modifications. Eagle River gap is on the Phoenix property and is now being explored by the Keweenaw Copper Company.

On the way we pass in Section 28 the Natick Gap leading over to the Humboldt property (Sections 16 and 21) probably marking a considerable vein or throw. Close to the Eagle River Gap is the Phoenix property. Then we come to the Eagle River section described in Volume I, Part II, pages 117 to 140, so that we need only reproduce it in Figure 34 and give a condensation here.

-2, and -1, Ss. 16872 and 16871 are the Great Copper Harbor conglomerate. Then we have in the EAGLE RIVER series:

(1) A[1] and M, (2) Ss. and conglomerate, (3) M, (4) Ss., (5) M, (6) Ss., (7) M, (8) Sp. 16869 Ss., (9) M Ss. 16864-16868, (10) A and M, (11) AM, (12) A and M, (13) ophitic melaphyre with prehnite, copper and datolite, (14) (15) and (16) melaphyre (709)

(17) Ss. and conglomerate, (18) M with pink prehnite (Sps. 16863 to 16860) (19) Ss., (20) AM. (21) Ss., (22), (23), (24) and (25) AM, (26) Ss., (27) AM, (ophite), (28) Ss. (1159)

(29) AM, (30) AM, (31) AM, (32) (13) A and M, (33) (10) A and M, (34) (14) A and M, (35) (28) Ss. (fault) (1272)

(36) (21) A and M, (37) (16+10) A and M and covered, (38) (14) M (Sp. 16859) (39) (80) M (Sp. 16858 and 16857, ophite), (40 and 41) (54) covered, (42 and 43) (50) M largely covered, (44) sandstone top, to scoriaceous amygdaloid (1417)

This is the end of the Eagle River series structurally as Bed 45 is one of the Ashbed diabases or melaphyre porphyrites in type, and Marvine draws the line here. The bed above No. 44 is, however, an amygdaloid conglomerate of the type of those below rather than those above, the last typical sandstone being 35

ASHBED GROUP (45) brittle fine grained M, Sps. 16856-16854, (86 feet) (1503) (46), (47) Sps. 16853-16850, (48), (49), (50), (51), (52), (53), (54), (55) Thin AM's with altered olivine, laumontite, prehnite and copper in foot of amygdaloid zones (1630)

(56), (57)? (58) M, (59) and (60) AM and M (61) and (62) AM and M (Sp. 16848) (63) seam of sandstone (I think Beds 64 and 65 may be the same bed, Sps. 16847 and 16846B), (1810)

(64) A, AM and M fault, (65) A, AM and M (16847-16846) (1990)?

I have examined one of the Wisconsin sections of this bed as follows:

Bed 65, Eagle River section,[2] February 24, 1909. A. C. Lane. Section 4607 U. of Wis. See Journal of Geol., 1908, p. 772 analysis. Is too thick. Augite color up to .000948÷.029=.033mm+. Ashbed diabase. Bed 65 Eagle River section, sample No. 7 of Rohns collection.

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[1]A stands for amygdaloid.
M stands for melaphyre.
Ss stands for sandstone.
[2]See Fig. 34 in envelope.

Augite is in granules generally, here and there in patches beginning to be poikilophitic. The granules are .10 to .05 mm. in size and smaller. A few large pieces apparently left from an early coarser crystallization run up to .2-3 mm.

Feldspar is quite varied in size, glomeroporphyritic, the largest aggregate is 3.5 mm. x 2; composed of laths each about 1.5 x 0.3. Albite twins parallel M (010) 21°.5 ex with 25°.5 and 14°. 2. The largest grain is Ab75 An25. The small feldspar laths probably nearly at right angles to P. and to M are about 15 x .03 mm; ex 4, 3-6, 4-5, 0-0, 1, 3 ave. 3°, and supposing them perpendicular to M and parallel to P indicate between Ab3 An and Ab5 An3. Olivine pseudomorphs into green serpentine and red iron oxides are generally irregular and not very common. 0.5 mm. is the largest. They are probably corroded remnants.

Iron oxides (magnetite) are in triangular octahedral sections up to about .35 mm. It is quite abundant original. There is some secondary.

Green substances replace olivine and feldspar phenocrysts and possibly fill miarolitic interstices.

This is an (oligoclase) melaphyre porphyrite of the ashbed type. As A. N. W. says it is related to Irving's bed 87. Cf. in the Isle Royale section, Volume VI, Pt. 1, pp. 173, 174, 213 foot of page. See 15515 (a) of Pl. V, 15438; Fig. 4, Pl. VI, p. 67, 15437-15441 Hole IX 328-385, which is, as I made, the equivalent flow on Isle Royale. It is a lucky coincidence that I figured just this flow. (See also pp. 159, 67, 170.)

This is probably near the center of the flow, at any rate quite augitic and not near the top.

The analysis made for Winchell is also given in Chapter II.

(67) A, AM and M, and (68) A, AM and M (I think one bed) (69) A, AM and M (Sp. 16843), (70) A and AM (2211)

(71) A and M, (72) M part covered (2288)

(73), (76) and (78) AM and M [porphyrites] part covered, (79)- (81) covered, 64 feet? First sandstone south of Ashbed (2496)

(82) AM and M, (83) Sandstone 3 inches and Am. conglomerate, (84) A and M porphyrite, (85) sandstone, (86) A and M, (87) A, A and M and M, Ss. 16840-16842 (154) (2840)

(This is the glomeroporphyrite to ophite analyzed by Pumpelly, (Ch. II) the phenocrysts sometimes red and sometimes green

Covered (position of the Mesnard) ————

CENTRAL GROUP

(90) M (part of 91?) Sp. 16839 (2927)

(91) Aphanitic diorite, Sp. 16838 (94) (3021)

(Upper bed like the Greenstone and ophite and as no distinct amygdaloids were recognized perhaps a part of it)

(91 to 108) Marvine classes as diorites (sometimes separating the light, what we call doleritic, type and the dark more poikilitic type, as separate beds. (92), (93), (94), (97), (98), (100), (102), (104), (106) are dark; (107) is alternating light and dark, the coarsest "hornblende" [augite] being 4 inches in diameter, 108 is the bottom (412) feet)

Total thickness 87 to 108 (1280) (4120)

Ss. 16839, 38, 36, 35, 34 and 33 are from Beds 90, 91, 92, 93 and 94 respectively.

Wis. Coll. No. 4605. Sec. 4605 is from the "Greenstone" ophite. Eagle River section Bed 108, (See Journal of Geology, 1908, p. 772 and A. N. Winchell's description. See also Geol. Sur. Mich., Vol. I, Pt. II, p. 136) is the lower 412 feet of the flow.

Section is thick since birefraction for feldspar is up to 650 mm.—^{6} for augite is up to 1350 mm.—^{6} i. e. 0.06 mm.?

Augite is in polysomatic grains and patches up to 3.7 mm; the largest seen is 4.2 mm. With this coarseness one can not be sure of the grain. It is much cut up by the feldspar. The larger iron oxides and olivine are crowded away from the center of the augite patches.

	Ex.	Ex.	Ex.	Ex.		
Feldspar (M)	18.7	21.4	26	39.9		
retardation	430			430		
Cf. Ab_1, An_1+						
		292.6		318.2	264.2	w K 271?
biref				270	400	
Near M		293		300	282	
biref				200	200	

Its composition is near Michel Levy's $Ab_3\ An_4$ or (fig. 194 in Rosenbusch) Ab_2An_3

Iron oxides, also occur in poikilitic patches enclosing the feldspar 1 to .5 mm. in diameter. The feldspar is older. Patches tend to be equant with traces of triangular section.

Olivine, (owing to the thickness it is not easy always to tell it from the augite), is in about .2 mm. rounded granules, one grain .5 mm?

Green substances, chlorite mainly, in interstices, probably miarolitic.

This is a typical luster mottled melaphyre or "ophite" as I have called them. (See Vol. VI, I, pp. 156 and 158) The feldspar checks well. (See also pp. 74, 125-127, 136-137, 167, 175). The specimen was probably 35 to 60 feet from the base of the flow.

The analysis given in the Journal of Geology (and also in Ch. II) should be compared with Volume VI, Part I, pages 147, 215, VII, X,[3] XIV[4] and Ovitz's analysis. Notable are the close checks in Al, Ca, Na_2. The variation in SiO_2+TiO_2 may be analytical. That from Fe to Fe_2 is important. I cannot understand the absolute absence of K_2O in the analysis by the U. S. Geological Survey.

(The Allouez conglomerate is omitted, being cut out by the slide. The remaining beds are ophites, with amygdaloid tops, cut in the workings of the Phoenix mine.

(109) AM and M	(42)
(110) AM and M	(24)
(111) AM and M	(82)
(112) AM and M	(31)
(113) AM and M	(24)
(114) AM and M	(15)
(115) AM and M	(9)
(116) AM and M	(12)
(117) AM and M	(28)
(118) AM and M	(20)
(119) AM and M	(57) 115 feet wide
(120) AM and M	(18)
(121) AM and M	(103) (7 mm. ophite, probably the Mandan ophite mottles "0.3 inch").
(122) AM and M	465
(123) AM and M	

[3]There are misprints, Fe_2O_3 should be 2.86 and CaO 10.28.
[4]An old and hence inaccurate analysis of the same flow.

Cliff Mine Section.

This Cliff mine section (Fig. 35)[5] by Mr. Klepetko, dates from before my time. I have not thought it desirable to have it redrawn. One may see in the older reports of commissioners of Mineral Statistics a map which shows the impression the amygdaloid bands give in mining near a cross-vein where the alteration and pseudamygdaloid effect is so great that without careful study it is impossible to make out the belts. Were I making up the section anew no doubt I should use a trifle different language. But the main horizons, the Calumet and Kearsarge conglomerates and the Kearsarge amygdaloid, are correctly determined, I think. The mottled gray trap at the bottom of Hole A may be Manitou 3 bed 66 (Fig. 29) a 10 mm. ophite. Drill hole E and Manitou 3 d 2 S. agree in their well-defined ophites. The heavy bed of trap second above the Calumet conglomerate persists (Manitou 3. Bed 42).

The Houghton conglomerate is not shown but it is very often an amygdaloid conglomerate in the Manitou 3 section. It is the eleventh soft belt about 600 feet below the Allouez conglomerate and here we found amygdaloid flow, No. 2, at just the same number of belts and distance from the "slide."

There has been much recent drilling on this section.

§8. KEARSARGE LODE.

After leaving the Cliff there has been but little done in the way of systematic sectioning until we cross Allouez Gap and come to Calumet. The attention of mining men has of late been focused on the Kearsarge lode. This has been followed almost continuously, not merely in the sections here given, but in numerous other holes, pits and explorations. It is clearly identifiable in the Mandan (Fig. 25) and has been repeatedly struck in drill holes and a shaft has been sunk upon it, though in the Empire and Clark-Montreal sections it is not so clearly identifiable and may be cut out. In the Manitou it was well-defined and specimens have been obtained showing copper well. It is located on the Central property, and was identified by Hubbard on the Miskwabik, Section 5, T. 57 N., R. 31 W. It was met again on the Cliff and beginning at the south end of this property at the Ojibway, it has been drilled, explored and mined at very frequent intervals. Yet while the sections are in some respects similar, they are in others different.

For the thirty-two miles that has been followed, the large pheno-

[5]In envelope.

crysts of feldspar persist, sharply distinct from the ground mass (Plate VII the two cores in the third row from the left, show lode and foot) and from each other, but very little agglomerated. The Wolverine sandstone persists as a sandstone, though it varies enormously in thickness. It is curiously lacking in the felsitic debris which is so conspicuous above. When thick, it is dark red, but it may be very epidotized and turned yellowish. A slide may cut it out entirely.

The porphyritic trap which is the foot of the Kearsarge lode is an ophite, but the mottling does not show close to the margin. The rate of increase (A) is less than half that in the Greenstone. It is in some places one heavy bed 100 to over 200 feet thick. On top of this will be the well-marked cupriferous amygdaloid which is the Kearsarge lode and then there will be no difficulty in identification. But this is not everywhere so. In places it will be broken up into successive gushes, each with its own amygdaloid and decrease of grain due to cooling. Besides this there may be irregular streaks of amygdaloid in the bottom of the trap. A few illustrative sections may be given, taken between the Cliff and the Franklin Junior. (a) While at the Cliff the distance from the Kearsarge to the Wolverine sandstone was about 90 feet and the Kearsarge foot was thick and characteristic, at the Ojibway there is a little red sandstone not far above the Kearsarge amygdaloid (cf. Caldwell Hole 1, at 148 feet) and there are from four to eight streaks of Kearsarge amygdaloid within 140 feet above the Wolverine sandstone. The lode enters near the north quarter-post of Section 13, T. 57 N., R. 32 W. The shafts are sunk in the foot wall, so that the drifts over to the lode give numerous very short sections. Though so near the Gratiot there are here a number of amygdaloid belts. The formation is badly faulted just here. I am tempted to connect this fact with certain gaps in the Greenstone Range as shown on Plate IX.

(b) The Seneca is the next property and has the outcrop of the lode in the northwest quarter of Section 23, T. 57 N., R. 32 W. The exploration by this company upon the lode was not done in time to be incorporated here.

(c) Gratiot Mining Co. This is a subsidiary of the Calumet and Hecla just beyond the Mohawk and less than a mile from the Ojibway. *Gratiot drill hole 31,* Section 27, T. 57 N., R. 32, is a very typical hole. The angle of hole is 55°,—practically at right angles to the dip.

1. Ophite, Kearsarge hanging (30+)
   Trap d 31. 28-58
2. Kearsarge amygdaloid and foot (202)
   Amygdaloid d 31. 58-66
   Foot trap d 31. 66-260
   Large porphyritic crystals of labradorite are abundant, but it is also mottled; at 104, 145, 154, 191, 230 feet
   the augites are 2, 3, 4, (5), 1-½ mm. across.
   The rate of increase A=.000127. Abnormal for an ophite, but characteristic for this.
3. Wolverine (25)
   Red sandstone d 31. 260-280
   Fine grained, red; at right angles to core
   Basic amygdaloid conglomerate 280-285
4. Amygdaloid (5)
   Poor d 31. 285-290
   The beds here are easy to identify. The Kearsarge amygdaloid is also opened up by shafts.

(d) Next is the Mohawk mine in which the amygdaloid occurs in two forms, a red and a hard grey or green form near the cross-fissure that was filled with Mohawkite, etc., described by Koenig.[1] In some parts there is probably a double lode. The lode is opened up by six shafts. (See Pl. IX). See also the discussion of the mine waters, Chapter VII. The dip varies from 36° to 38° in Shaft No. 5.

(e) After passing for a few acres into the Fulton property the lode is next developed by the Ahmeek mine. Mr. Frank Klepetko gives a section of the Ahmeek open cut as follows, dip 42°.

At 0, 120, 320, 460 amygdaloids.

At 740 Calumet conglomerate No. 13.

From base of Calumet conglomerate unexplored, then:

1050-1150 Trap; 1150-1170 am., to 1230 trap; 1230-1245 am., to 1330 trap; 1330-1345 am., to 1545 trap; 1545 fluccan, then Kearsarge conglomerate to 1610 and sandstone to 1620. From base of Kearsarge conglomerate 1620:—

0-40 amygdaloid; to 200 and 230 trap, 230-250 am., to 370 trap; 370-380 am., to 450 trap; 440-460 am., to 480 trap; 480 am.; then unexplored; at 1130-40 Kearsarge amygdaloid.

(f) It is next tapped by the Allouez which not having the outcrop of the lode had to come down on it by a shaft nearly vertical but inclined 80° and curving into the dip of the lode. This gives, of course, a section above the lode, but it was much prolonged, being cut obliquely and belts appear on one side of the shaft at greater depths than on the other.

1. L. S. M. I., 1901, pp. 62-64. Am. Jour. Sci., 1900, p. 439.

(g) The next property is the North Kearsarge opened by shafts on the lode, now a part of the Osceola Consolidated and controlled by the C. & H.

(h) Next comes the Wolverine, the great success on the Kearsarge lode. As this is a small property the management have done some cross-cutting to to see what they have, so that there is a pretty good section here. In different parts of the mine there is an east and west vein,—at least two amygdaloids.

The dip is 40° to 41°,—41¼° at the 24th level of Shaft 3.

In the 8th and 13th levels; we have above the lode beginning at the north end in each case and reading down, trap and amygdaloid alternating.

WOLVERINE 8TH LEVEL CROSS-CUT	No.	Width.	Thickness.
Water fresh, T. 48° F., Sp. Gr. 1.001-	14	33	
Trap		31	(53)
Amygdaloid (including a separate flow)	13	36	(23)
Trap		43	(28)
Marked am. gray and white, wet	12	12	
Trap		38	(33)
Marked am.	11	15	
Ophite fine grained		40	(36)
Perhaps not top of flow, water has Sp. Gr. 1.000	10	9	
Trap		30	(25)
Marked hard amygdaloid	9	17	
Trap		36	
A mere skein, chloritic large amygdules	8	12	
Ophite, 5 mm		108	(112)
Red bordered amygdaloid	7	9	
Fine grained trap		34	
	6	7	
Fine grained trap		58	(70)
Kearsarge lode.			

The 13th level cross-cut is much longer and reached through the Kearsarge conglomerate.

WOLVERINE 13TH LEVEL CROSS-CUT

The Sp. Gr. of the water in this was 1.000. The N. W. end of drift from the hanging of the Kearsarge amygdaloid in August 1905 was distant horizontally 1365 feet.

	Width.	Thickness.	Thickness above K. A. m.
Trap			
Kearsarge conglomerate No. 10, dip 39°-40°	44	(29)	
Base from hanging of Kearsarge amygdaloid	1323		(860)
Amygdaloid	11		
Ophite (augite grain 2 mm. 31 feet from foot of amygdaloid	95	(68)	
Amygdaloid red with green specked amygdules, apparent dip of contact 42°. Trap; coarse feldspathic, with decomposed pseudamygdaloid streaks but no clear division	22 164	(122)	(792)
Amygdaloid	10		(670)
Trap	97	(70)	
Amygdaloid	11		(600)
drifted upon			
Trap, damp about 30 feet from base	65	(50)	
Amygdaloid, a well-marked band and characteristic, like No. 18	33		(550)
Trap	74	(70)	
Amygdaloid poor	5		(480)
Trap	68	(50)	
Amygdaloid	6		(431)
Trap	23	(19)	
Amygdaloid with well-marked contact	10		(412)
Trap (a seam of laumontite crosses the drift striking more west and dipping to north)	84	(62)	
Amygdaloid with side drift, marked, coarse, pink and white and chloritic	26		(350)
Trap, ophite	45	(46)	
Amygdaloid. This belt is at the bottom coarse, laumontitic, blotched and includes one or two separate small flows with genuine marked amygdaloids at the top and pipe amygdules at the base of the next flow, at e g. 49 feet from the base and at the very top No. 18	88	(26)	(304)
Trap, solid ophite	40	(58)	
Amygdaloid marked calcitic with red No. 17 ground	22		(220)
Trap a good deal specked and skeined with am. not very coarse	138	(104)	
Amygdaloid carries some copper and was stoped a little, and a long drift run No. 16	24		(116
Trap	30	(35)	
Poor amygdaloid No. 15	5		
Trap	120	(81)	

At 55 feet from foot was a seam dipping steeply to the south yielding a fresh water, Sp. Gr. 1.000, T. 51°.

The section below the lode which is about 7 feet thick is given in the cross-section from the 11th level.

	Width.	Total.	Thickness.
Foot of lode			
Trap (Porphyritic)	287 ft. to	287	(190)
Sandstone (Wolverine) No. 9	32	319	(21)
Trap	87	406	(57)
Amygdaloid	15	421	(10)
Trap	205	626	(135)
Amygdaloid	5	631	(3)
Trap	64	695	(42)
Amygdaloid and epidote	17.5	712.5	(11)
Trap	103	815	(68)
Amygdaloid	32	849	(21)

This is typical, like the Gratiot.

(i) The lode is next opened by the South Kearsarge branch of the Osceola directly on the lode.

(j) The Centennial follows next with two shafts also directly on the lode, diverging in strike and dip, the S. W. one 38.5°, the N. E. 42°.

(k) Next comes the Calumet and Hecla Mining Company Kearsarge shafts 19 and 20 and 21, to locate which holes were drilled near Kearsarge 19 and 20, lettered A, D and C while B and others were near Kearsarge 21. These are given below, in Section 9. See also Figure 37.

(l) Between 20 and 21 the lode passes into the Laurium property, Section 24, T. 56 N., R. 33 W. I have no record of explorations here.

(m) Beyond the Calumet Shaft 21 the lode just cuts the corner of the Torch Lake property. (See Section 10 and Fig. 38.)

(n) It next goes into the property of the La Salle Mining Company, Section 34, T. 56 N., R. 33 W., and the north part of 3 and 4, T. 55 N., R. 33 W. The north part is the old Tecumseh, the south part the old Caldwell. Here are some difficult sections as follows:

La Salle Mining Co. This property includes the old Tecumseh and adjacent lands near the S. line of T. 56N R. 33W (Section 34, 33, E. half and S. E. of S. W. of 32; N. half of 3; N. half of 4; and N. half of S. E. of 4) including practically the lands between the Osceola and the Rhode Island.

The holes on the south part of this property show a not uncommon phase of the Kearsarge amygdaloid in which a number of amygdaloids occur. The same thing occurs at the Ojibway and on the Rhode Island. But down at the Arcadian section it is all together again.

See the correlation under Bed 3.

Caldwell drill hole 1. ⅛ mile E. and ⅛ mile S. of N. W. corner of Sec. 3, dip 45° to S 50° E.

1. Overburden (40)
2. Feldspathic ophite (80)

Amygdaloid Cald. d 1. 40 to 47?

1 to 2 mm. chlorite mottles, red to a colder gray, with forms suggesting pseudoamygdules after porphyritic crystals; at the end red, white and gray epidotic.

Amygdaloidal trap d 1. 47 to 58

Red with green amygdules, then gradually coarsely amygdaloid and feldspathic.

Trap d 1. 58 to 120

Chloritic, blotched with an epidote laumontitic seam at 22°, grows coarser toward 83, at 92 poor, specked and finer, at 102 mottles begin (3-4 mm.) then finer.

Cf. 62 Arcadian d 1. 262 to 385
C. & H. C. 135 to 226

3. Melaphyre (28)

Amygdaloid Cald. d 1. 120 to 126

Red with some *copper*, chloritic and pink amygdules.

Trap d 1. 126 to 148

Feldspathic but porphyritic crystals are not well-defined.

If this bed is the bed above the Kearsarge, the total for the Kearsarge beds with the various splits of the Kearsarge amygdaloid would be 133 feet, which checks well enough with Franklin Junior No. 4 (133 feet) and Rhode Island No. 4 639 to 746 feet. (109)

The porphyritic crystals are absent in this bed and only the copper would lead one to suspect that the top was the Kearsarge.

The bed below is certainly Kearsarge.

We may perhaps best compare the following beds:

1. 148 to 281=(133) ft. with five beds (14), (31), (22), (34), (32) feet thick:
2. 72+;
3. 63 to 93+;
4. 202 to 311=(109) with five beds (7)?, (14), (28), (15), (45), feet thick;
5. 49 to 151+ a vertical hole=(73+) feet with four beds (9+), (12), (18), (28+) ft. thick;
10. 528 to 628 a vertical hole (71) feet with three beds (30), (18), (17) feet thick;

Tecumseh 1. 228 or 256 to 410 (154) in one bed;

Rhode Island 1. 333 to 463 (130) with at least three beds (48), (34), (48) feet thick;

63 Arcadian (1. 358 to 428+2. 42 to 143) 109 feet thick.

We call these beds, but their irregularity and the similar peculiar trap between each of them show that they are presumably overlapping gushes of the one flow. They are *not* repetitions by faulting, for when the bed is really one thick flow, as at the Tecumseh and farther north, the grain is different and an ophitic mottling comes out characteristic of thick flows.

4. Sediment (0)

Just a little? Much lost, fissure?

5. Beginning of Kearsarge No. 1, porphyritic traps (plagiophyres) (14)
   Amygdaloid d 1. 148 to 155
   Epidote and gray or white amygdaloid.
   Trap d 1. 155 to 159½
   Amygdaloid d 1. 159½ to 160
   Trap d 1. 160 to 162½
   With marked porphyritic crystals.
6. Kearsarge amygdaloid and foot No. 2 (31)
   Amygdaloid d 1. 162½ to 164
   Contact well marked, only 5° from right angles to core.
   Trap d 1. 164-193
   Porphyritic.
7. Kearsarge amygdaloid and foot No. 3. (22)
   Amygdaloid d 1. 193 to 205
   Trap d 1. 205 to 215
   Porphyritic
8. Kearsarge amygdaloid and foot No. 4 (34)
   Amygdaloid d 1. 215 to 221
   Gets lighter, epidotic at base.
   Trap d 1. 221 to 249
9. Kearsarge No. 5 (32)
   Amygdaloid d 1. 249 to 253
   With copper.
   Trap d 1. 253 to 281
   From d 1. 255 to 267 very fine grained with few phenocrysts, at 281 is very fine grained; at 295 is a fissure at 5° from right angles to the core, but a seam makes 18°.
10. Wolverine sandstone No. 9 (7)
   d 1. 281 to 288
   Beneath is broken and fissured, with a calcite vein.
11. Melaphyre (14)
   Amygdaloid d 1. 288 to 295
   Trap d 1. 295 to 302
12. Melaphyre (4)
   Amygdaloid d 1. 302 to 305
   Trap d 1. 305 to 306
13. Melaphyre (10)
   Amygdaloid d 1. 306 to 312
   Trap d 1. 312 to 316
   With clasolites.
14. Melaphyre (4+)
   Amygdaloid d 1. 316 to 320. Practically these are all one heavy amygdaloid belt which does not seem to appear in the Arcadian section.

Caldwell drill hole 2. About 100 feet N. of No. 1 Caldwell along the strike.

1. Overburden to d. 2.25 (125)
2. Feldspathic melaphyre (47)
   Amygdaloid Cald. d 2. 25 to 39
   Green and white specked amygdules.
   Trap Cald. d 2. 39 to 72
   Coarsest, feldspathic about 48, then finer.

3. Kearsarge amygdaloid and trap
   Amygdaloid d 2. 72 to 75
   Red with *small* porphyritic crystals.
   Amygdaloidal trap.
   Coarse, cf. Cald. d 5 at 62 feet.

Caldwell drill hole 3. Further N. W., therefore it should strike the same point at a greater depth.

1. Ophite 38+
   Trap d 3. 0 to 38
   Coarse 5 mm. mottles.
2. Ophite 25
   Amygdaloid d 3. 38 to 45
   Trap d 3. 45 to 63
   Fine grained, laumontitic ophite.
   Cf. d 2. 25 to 72
3. Kearsarge amygdaloid and foot
   Amygdaloid d 3. 63 to 74
   Epidotic, red at first, at 64 a contact showing inclination? at 67 the odd shaped pseudoamygdules which may be after the porphyritic feldspar, which is yellow-green, blue-green and white; epidotic amygdaloid to d 3. 74.
   Trap d 3. 74 to 93+
   Regular Kearsarge foot.

Caldwell drill hole 4.
   Overburden (73)
1. Feldspathic ophite
   Amygdaloidal trap d 4. 73 to 147
   Coarse at first and growing coarser.
   At 90 and 115 feet there are mottles
   3-4? and 5-7 mm.
   At 142 is a vertical seam with copper nearly parallel to the core.
2. Melaphyre.
   Amygdaloid d 4. 147 to 157
   Hard, fine grained, with scattered amygdules.
   Trap d 4. 157 to 166
3. Ophite
   Amygdaloid d 4. 166 to 173
   Amygdaloidal trap d 4. 173 to 187
   Poor, some signs of porphyritic crystals.
   Trap d 4. 187 to 202
   Ophitic? fine grained and decomposed at 191-2
   Here at 202 feet begin the Kearsarge group.

4. Kearsarge amygdaloid and foot No. 1 (7)
   Amygdaloid d 4. 202 to 209
   Growing finer, reddish, with porphyrite crystals to 209.

At 209 an epidotic contact nearly at right angles to the hole.

Trap d 4. 209 to 223

Fine grained reddish porphyrites, not amygdaloid to 223.

5. Kearsarge amygdaloid and foot No. 2

Amygdaloid d 4. 223 to 227

Small chloritic amygdules were like the bottom of a flow.

Trap d 4. 227 to 251

Seamed and decomposed at the top, some joints nearly parallel to the hole. Porphyritic crystals conspicuous, grows finer from 244 down

6. Kearsarge amgdaloid and foot No. 3

Amygdaloid d 4. 251 to 258

Epidotic

Trap d 4. 258 to 266

Typical Kearsarge foot. The labradorite phenocrysts are as much as 30 mm. long.

7. Kearsarge amygdaloid and foot No. 4

Amygdaloid d 4. 266 to 269

Epidotic

Trap d 4. 269 to 311

Contains some big porphyritic crystals, toward the base becoming a dense blue-black trap.

8. Wolverine sandstone (No. 9) at (311)

Small fragments of conglomerate and crushed stuff below.

Cf. 64 Arc. 2. 178

9. Feldspathic ophite 7 mm. (66)

Trap d 4. 311 to 377

About 1 mm. mottles at first, chloritic not porphyritic, at d 4. 323 is a little seam with *copper*, faulting below, and mottles up to 7 mm.

Cf. 65 Arc. 2. 178 to 262

10. A vein from 369 to 377.

11. Ophite (83)

Amygdaloid d 4. 377 to 381

Pink amygdules on dark ground.

Trap d 4. 381 to 392

Amygdaloid bomb, not contact, 392 to 394?

Trap d 4. 394 to 460½

Massive, uniform, ophitic, growing redder and finer from 431 on. Cf. 66 Arc. 2. 262 to 315

12. Ophite (15)

Amygdaloid d 4. 460½ to 465

There is a little seam of sandstone, banded.

Trap d 4. 465 to 475

13. Marked sedimentary contact at d 4. 475

14. Amygdaloidal melaphyre (58)

Amygdaloid d 4. 475 to 482

Trap d 4. 482 to 483

Fine grained, dark chloritic, with basal amygdules.

Cf. 68 Arc. 2. 315 to 464 which also has sediments above and below.

15. Conglomerate d 4. 483 to 486 or 490

Well-marked felsitic conglomerate. Then possibly a gray trap boulder from 486 to 488, then dark basic conglomerate with brown sandstone and

white and black scoria, shading into amygdaloid. This bed 182 feet only below the Wolverine is quite likely to be mistaken for it, and probably has been in the early work at the Tecumseh and elsewhere. It seems fairly persistent. Cf. Belt 59 of the Central mine section; Calumet and Hecla A 10, 401 to 405 ft.; 67 or 69 Arcadian, about 133 to 286 ft. below the Wolverine; Franklin Junior No. 3 at 535 to 539 ft. where the Wolverine is at 373′ 11″ to 376′ 9″.

All these beds show under the Wolverine heavy ophites with a tendency to scoriaceous amygdaloid tops containing a little red sandstone.

16. Feldspathic ophite (24+)
d 4. 490 or less to d 4. 514 or more.

Caldwell drill hole 5. Vertical. Hence the true thickness is about .7 of that along the hole.

1. Overburden top 49
2. Kearsarge foot 9+
Trap d 5. 49 to 62
Fine grained at first. Along from 56 to 58 this has large porphyritic feldspar crystals, up to 25+ mm. and is a fine grained, (say 2 mm.) ophite.
3. Kearsarge amygdaloid (*not* the uppermost one) No. 2 and foot (30)
Amygdaloid d 5. 62 to 79 17
Typical Kearsarge amygdaloid, a clay seam at d 5. 72, after which it is coarser.
Trap d 5. 79 to 97
Porphyritic greenish gray plagioclase. At 95 they become pinker and so more conspicuous.
4. Kearsarge amygdaloid and foot No. 3 (25)
Amygdaloid d 5. 97 to 104
Marked epidotic
Trap d 5. 104 to 112
Fine grained to 106, then coarser with the porphyritic plagioclase plain.
5. Kearsarge amygdaloid and foot No. 4 39+ (28+)
Amygdaloid d 5. 112 to 120
Epidotic with pink crystals
Trap d 5. 120 to 151+
Matches No. 4 at 281 to 313; fine grained, black.

Caldwell drill hole 6 did not reach ledge.

Caldwell drill hole 7 dipped with the lode.

Caldwell drill hole 10. Vertical. To determine the top of the Kearsarge amygdaloid for their shaft. From indications in the drill cores the dip is about (tan-1 5:4) 51° ⅓, but this is not comparable in accuracy with the correlation by dip.

1. Overburden 38
2. Ophite (15)
   Trap d 10. 38 to 56
3. Ophite 34 (24)
   Amygdaloid d 10. 56 to 67
   Trap d 10. 67 to 90
   Faintly mottled.
4. Fine grained melaphyre 10 (7)
   Amygdaloid d 10. 90-96
   Trap d 10. 96-100
5. Melaphyre 10 (7)
   Amygdaloid d 10. 100 to 110
   Contact at 110 sharp, red, fine grained, dip (tan-1 5:4=51°⅓)
6. Feldspathic ophite 32 (23)
   Amygdaloid d 10. 110 to 124
   Specked at 119 pink, faintly mottled, prehnitic.
   Trap d 10. 124 to 142
7. Melaphyre 9 (6)
   Amygdaloid d 10. 142 to 145
   Gray
   Trap d 10. 145 to 151
   Fine grained.
8. Ophite 117 (83)
   Amygdaloid d 10. 151 to 160
   Coarse red and pink
   Trap d 10. 160 to 253=268?
   Fine grained, specked with amygdaloid to 181, 3 mm. mottles 191 to 204, 2 mm. at 221, growing finer.
   The relatively slow decrease of grain shows the oblique section of the bed. There are chloritic amygdules at about d 10. 253
9. Feldspathic melaphyre 41 (29)
   Amygdaloid d 10. 268 to 278
   Pink and white amygdules, almost like pseudamygdules after porphyritic feldspar.
   Trap d 10. 278 to 309
   Chloritic with rather coarse feldspar, red to 309.
   Flows 10 and 11 are probably all one.
10. Feldspathic ophite (7 mm?) (75)
   Amygdaloid d 10. 309 to 311
   Trap d 10. 311 to 337 to 415
   Chloritic and specked; at 337 epidote with *copper*. About 345, 2 mm. feldspar, coarsely feldspathic and about 370, 12 mm. feldspar, and faint (7 mm?) augite mottles. Toward 412 it grows finer and reddish. Cf. R. I. d 4. 535 to 611, and Caldwell d 4. 73 to 147, and Arc. 62 d 1. 262 to 385, or should this correspond to d 10. 451 to 527?
11. Melaphyre 36 (25)
   Amygdaloid d 10. 415 to 433
   Marked contact, fine grained amygdaloid with red ground, pink amygdules and feldspar to 426, then epidotic to 433.
   Trap d 10. 433 to 451
   Blotched to 441, epidotic to 444, decomposed, coarse to 449. Cf. R. I. d 4. 611 to 624; Caldwell d 4. 147 to 166.

12. Ophite (54)
Amygdaloid d 10. 451 to 462
At 459 much seamed and fine.
Trap d 10. 462 to 527
Blotched and faulted parallel to a fault at 22° with the core, then chloritic, coarse, feldspathic, mottled 2 to 3 mm. at about 510, altered olivine at 513, joints at 31° to core perpendicular to dip? At 527 a seam, perhaps cutting out something. Cf. R. I. d 4. 624 to 631 and 631 to 639; Caldwell d 4. 166 to 202; Caldwell d 1. 148.
13. Kearsarge amygdaloid and foot No. 1 43 (30)
Amygdaloid d 10. 528 to 530
Specked amygdules, epidote and porphyritic crystals.
This is only (528 to 620) 92 feet above the Wolverine along the core or something like (65) feet true thickness. There appears to have either been something cut out in this hole or doubled in some of the others, and as the less disturbed and more regular the grain is, the more nearly we have the customary thickness of over 100 feet, it is probable that the formation is cut out here.
Trap d 10. 530 to 571
Well-marked porphyritic labradorite.
14. Kearsarge amygdaloid and trap No. 2 (18)
Amygdaloid d 10. 571 to 580
Well-marked epidotic with porphyritic crystals to 573, with calcite and green prehnite to 580.
Amygdaloidal trap d 10. 571 to 596
Porphyritic crystals not marked to 585, some sediment and porphyritic crystals to 589, some especially long green ones to 596.
15. Kearsarge amygdaloid and foot No. 3 24 (17)
Amygdaloid d 10. 596 to 600
Trap d 10. 600 to 612
Mottles ½ mm. at 600 to 601; porphyritic crystals, well-marked
Amygdaloid d 10. 612 to 620
Cf. R. I. d 4. 725 to 746
63 Arc.
16. Wolverine sandstone 19 (13)
Sandstone d 10. 620 to 634
Dip 48° ¾
Conglomerate d 10. 634 to 639 or 665
Much brecciated, shading into amygdaloids with numerous slips at an angle of 40°, and broken and disturbed sandstone and conglomerate. Cf. Caldwell d 4, at 311, R. I. d 4 at 746, 64 Arc.
17. Ophite
Amygdaloid d 10. 665 to 683
Trap d 10. 683 to 699
Ophite with 1-2 mm. mottles. Cf. 4. 311+. In holes less deep the sandstone is mainly gone and here it is the overhanging Kearsarge amygdaloids,—an effect which might be produced by an upthrust on a flat hade.

Tecumseh. N. E. part of Sec. 34, T. 56 N., R. 33 W., near shaft. R. M. Edwards put down two holes. Having put down No. 1 about at right angles to the formation, and struck the Kearsarge, he then went back to the outcrop of the Kearsarge and in Hole No. 2 aimed at a point 265 feet down in Hole 1, thus dipping with the formation at an angle of about 42°, and remaining in the lode practically all the way.

No. 1 is inclined at an angle of 45°.

1. Overburden
2. Feldspathic ophite 8 mm. 130+?
   Trap d 1. to 90 At 25, 45, 86
   mottles are 8, 7, 1–2 mm.
3. Doleritic melaphyre
   Amygdaloid Tec. d 1. 90 to 92
   Trap d 1. 92 to 113
   Chloritic doleritic vein 92 to 93; at 106 somewhat glomeroporphyritic.
4. Doleritic ophite 7 mm. 111
   Amygdaloid Tec. d 1. 115 to 122
   Poor, perhaps not a real top, with small amygdules and calcite.
   Trap d 1. 122 to 226
   At 155 marked doleritic, coarse feldspar with chloritic amygdules, then faintly ophitic; at d 1. 205 and 212 feet the mottles are vaguely 7 mm. and 1 to 2 mm. respectively.
5. Copper bearing lode, feldspathic melaphyre (31)
   Amygdaloid d 1. 226 to 228
   Red and white with copper. Cf. Cald. d 1. 120 to 126 to 148.
   Trap d 1. 228 to 257
   Coarse, feldspathic, with curious amygdules, but no plainly porphyritic crystals.
6. Kearsarge amygdaloid No. 1 and foot (150)
   Amygdaloid d 1. 257 to 274
   Trap d 1. 274 to 407
   At 281 to 284 the labradorite crystals are quite conspicuous. The ophitic mottling becomes apparent at:
   305, 318, 342, 358, 388 feet where the mottles
   are 2–3, 4–5, 7+, 3–4, 2 mm.
7. Basal amygdaloid or Kearsarge No. 2 (3)
   d 1. 407-410. Coarse, grayish white, with *copper*.
   Gradual transition to Wolverine sandstone by epidote band.
   This was first mined on as Kearsarge amygdaloid.
8. Wolverine sandstone (11)
   Amygdaloid conglomerate d 1. 410 to 421
   Amygdaloid and gray sandstone within 7° of right angles to core.
9. Melaphyre (4)
   d 1. 421 to 424′ 8″
   Crushed, decomposed, ending in feldspathic, poor amygdaloid.

(o) Rhode Island, Franklin and Arcadian. The Kearsarge lode is, I think, also identifiable in the Rhode Island, Franklin and Arcadian sections described below. (Figs. 40, 41 and 42.) Beyond to the south I have not yet been able to identify it, which is the more strange since it is of good thickness at the Arcadian and it

ought to be exposed somewhere between Houghton and Hurontown where I have made careful search at its horizon without identifying the peculiar and characteristic trap, though exposures are frequent.

§9. CALUMET (FIGS. 36 AND 37 AND PLATE IX.)[1]

The cross-cuts from the Calumet and Hecla conglomerate of the Calumet and Hecla Company and especially the system of hoisting from an inclined lode by vertical shafts of the Tamarack Mining Company have afforded abundant opportunities for sections summarized in Figures 36 and 37. The sections of the shafts extend nearly from the Copper Harbor conglomerates to the Kearsarge lode, which was, indeed, reached by a drill hole 970 feet from the bottom of Tamarack No. 2 shaft. To this drilling has recently been added, so that through the Lower Keweenawan down to the fault almost every belt liable to contain copper has been opened in more than one place. The old section (which we owed to the Calumet and Hecla Mining Company) published in Volume V must now be replaced by one more up to date. (Fig. 37.) Surface exposures indicate that the marked ridge through the center of Section 34, T. 57 N., R. 33 W., is conglomerate. The outer Copper Harbor conglomerate is on the lake side and trap on the southeast and it is topographically like the ridge at Carp Lake in the Porcupines. There are exposures on Section 34 and Section 3 just south that would seem to outline for us nearly the position of the Lake Shore trap belt and the Great Copper Harbor conglomerate. With the customary strike the boundary of the Upper Keweenawan would pass close to the northwest corner of Section 16. The drill section is as follows: All the drill holes were inclined 45° to S. 55° E.

Calumet drill hole 10. Elevation 390 feet above datum. 436 above Lake Superior, 1036 A. T. Location 880 NW. down hill from a wood road[2] on the 1079 ft. beach. Water flows from about 80 feet depth, temperature 43°. 3 F. Analysis of the water is given below. Dip of hole 45°; of rocks probably 25° (2:9) Depth 500 feet. Reduction to get thickness (0.975)

Overburden 56

1. Scoriaceous or amygdaloidal conglomerate d 10. 56-26 (10)
2.
   Trap d 10. 66-94
   Trap and green epidotized sediment d 10. 94-100
   This is quite possibly clasolitic or enclosed mud.
   Trap, faintly ophitic d 10.-131 (65)

[1] Figs. 36, 37 and Plate IX are in envelope.
[2] The Standard Mining Company put down a hole where this road turns off.

3. Feldspathic melaphyre (12)
   Amygdaloid d 10. 131-144
   Trap, fine grained d 10. 144-163 (31)
4. Ophite (3)
   Amygdaloid d 10. 163-166
   Trap, faintly ophitic d 10. 166-187 (21)
5. Ophite
   Amygdaloid d 10. 187-213 (26)
   Trap, faintly ophitic d 10. 213-239 (52)
6. Amygdaloidal conglomerate d 10. 239-255 (15)
   Bedding apparently cutting core at (1:3) 18°½ from right angles.
7. Feldspathic melaphyre d 10. 255-278 (22)
   Fine grained.
8. Melaphyre
   Amygdaloid d 10. 278-295 (16)
   A coarse amygdaloid with thomsonite (33)
   Trap d 10. 295-312
9. Sandstone d 10. 312-316 (4)
   Fine
10. Melaphyre (30)
    Trap d 10. 316-347
11. Melaphyre (44)
    Amygdaloid d 10. 347-358 (11)
    Trap d 10. 358-392
    Black
12. Feldspathic melaphyre (15)
    Amygdaloid d 10. 392-395 (3)
    Very faint, but contact shows.
    Trap d 10. 395-407?
    Fine grained with 1 mm. feldspar laths.
13. Ophite? (43)
    Amygdaloid d 10. 407-410? (3)
    Laumontitic.
    Trap d 10. 410-451
    Dark, faintly ophitic.
    Perhaps part of Belt 12 above
14. Conglomerate. The Great Conglomerate of Copper Harbor.
    d 10. 451-500=d 9. 283-500

    Fine grained, bedding at about 12½° from right angles to hole. It contains black grains, magnetite, laumontite and calcite, pebbles of amygdaloid, ophite and other basic rocks, anorthosite?! diabase, syenite, etc.

    This correlates closely with d 9. 283, and the dip to be inferred is 25°. (See Fig. 36)

    All of Holes 8 and 7 are in this bed and possibly 6 and 4, so there can be no question in calling it the "Great Conglomerate."

Drill hole 9. Elevation 402. 400 feet across the strike southeast from 10. Depth 550.

Overburden (47)

(5.) Ophite d 9. 47-65
Faint
(6.) Absent. Local
(7.) Amygdaloid d 9. 65-72
Trap d 9. 72-92
Hard and dense d 9. 86-90
(8.) Amygdaloid d 9. 92-99
Marked at first, turning to red feldspathic with occasional amygdules. At 103-105 a green rock with minute amygdules, like an altered mud.
Amygdaloidal trap d 9. 99-113′ 6″
Toward the base red
(9.) Brecciated sediment or slide d 9. 113′ 6″-116=d 10. 312-316?
(10.) Trap d 9. 116-203
Faintly ophitic
(11 and 12.)
Amygdaloid d 9. 203-205
Amygdaloid trap d 9. 205-232
Trap d 9. 232-251
Fine grained, dark
(13.)
Amygdaloid d 9. 251-257 (6)
Red and green, feldspathic, poor.
Trap d 9. 257-283 (26) (32)
Fine grained
14. Conglomerate. The Great Copper Harbor Conglomerate
d 9. 283-500
At 322 dark red shales, at 12½°, while lower beds are at 18° and 24° from being at right angles to the drill core.
The difference is probably dip of deposition.

Calumet drill hole 8. Elevation 437. 720 feet southeast from No. 9, the other side of two roads at about 440 and 620 feet. The overburden was 50 feet thick. The depth was 510 feet, all in conglomerate. Dip (8:36) averages 24° from right angles to core.

(14.) The conglomerate was fine grained like the bottom of No. 9, but also coarser with syenite and dolerite pebbles,—Keweenawan material.

Calumet drill hole 7. Elevation 470. 690 feet from No. 8. The overburden is uncertain. It seems like 20 feet, then 30 feet of soft conglomerate, then 20 feet of sand. The depth was 512 feet all in conglomerate. Dip 13.5:54.

(14.) There was much basic sandstone and debris. The conglomerate was fine grained.

Calumet drill hole 6. Elevation 508. 720 feet from No. 7. Overburden 99. About 60 feet deep. The depth was 1110 feet. Dip (9.5:36) about as before. From 80-840 was conglomerate with pebbles of fine grained trap not uncommonly, and much sandstone of basic debris; at 131 was a fluccan

15. Trap d 6. 840-868 (27)
A fine grained trap, possibly a boulder or intrusive. There was no amygdaloid above but one below for two feet. I should have counted it only a huge boulder were it not that something similar comes in Hole 4.
16. The rest of the way was basic sandstone and pebbles.

Calumet drill hole 4. Elevation 517. 1367 feet from No. 6. There is a road crossing the line of section at 1040 to 1070 and the profile is at 530 elevation. Depth 500 feet. Dip (6:27) about as before. Overburden 40 feet on the incline, 30 feet thick.

14. Great Copper Harbor Conglomerate continued. d 4. 40-188
With syenitic pebbles frequent, also large dark pebbles of fine grained trap, less of basic sandstone, more of conglomerate.
Total thickness from d 9. 283 about (1400)
15. Trap d 4. 188-224 (36)
Fine grained, with no amygdaloid above or below and little sign of variation of grain;—a boulder or a sill? But the correlation with Hole 6 precludes the boulder idea. It seems fine for a sill, but deserves farther examination. From the foot of this trap it is estimated to be 7920 feet to Calumet conglomerate foot by E. S. Grierson.

Possibly beginning of Eagle River series 1.
16. Conglomerate.
The rest of the way is either rather fine grained conglomerate or red or dark sandstones, the latter with more basic matter. This heavy conglomerate, which occurs also through Holes 3 and 2, would be the Great Copper Harbor conglomerate if one calls No. 14 the middle or lays no stress on No. 15. I think we can hardly use 15 for division. I am not at all sure it persists or is a bed. In that case, 14, 15 and 16 would all be the Great Conglomerate. On the other hand 15 *may* represent No. 1 of the Eagle River section. So that we must be prepared to find 16 connected with 2, which is a heavy sediment to 9 of Eagle River. The base of this trap d 4. 224 is (if 28° is assumed for the average dip) above the base of the Calumet conglcmerate (7420)
Hence above the Mesnard (5940)
But if this be the thickness of the Eagle River (4259) and Ashbed (1681) combined, then the Eagle River group is enormously thicker than elsewhere. But with a thickening of these lava formations goes a thickening of the individual beds. This seems not to have taken place. Bed 15 is of questionable character anyway. I feel sure, therefore, that Bed 16 should be counted as belonging to the "Great Conglomerate." Even then we have much more in the Eagle River beds than might be expected. So that it is a fair question whether we should not also include Bed 23, which is so closely parallel to Conglomerate 22, which Irving rightly enough includes as practically part of the Great Conglomerate. Farther drilling will be needed before we know which of these traps persist. The section brings out well, however, the desirability of a term like Copper Harbor Conglomerate to apply to all these heavy conglomerates, full of debris of the Lower Keweenawan in which

the flows that were the last products of dying volcanic activity occur as lentils.

Calumet drill hole 3. Elevation 525. 690 feet from No. 3. The cross-section abreast is at 560 feet elevation. Depth 502. Dip (17:54) about as before. Overburden on the slant 13. There is said to be a foot or so of trap at first. Is this the same as d 4. 224 or only a pebble?

16. Conglomerate d 3. 25-237 (227)
    Center red, with streak of red sandstone, basic sandstone, and all kinds of pebbles, labradorite porphyrites, etc. Cf. Eagle River 8 to 6.

BASE OF COPPER HARBOR CONGLOMERATES. BEGINNING OF EAGLE RIVER SERIES.

17\.
    Amygdaloid d 3. 237-240
    Marked white and laumontitic
    Trap d 3. 240-255
18. Ophite
    Amygdaloid d 3. 255-260
    Trap d 3. 260-290
    Mottles faint
19\.
    Amygdaloid d 3. 290-294
    Trap d 3. 294-325
    Fine grained with white calcite blotches and streaks on a gray ground; possibly a contact of a gush at 305.
20. Conglomerate, scoriaceous amygdaloidal d 3. 325-326
21\.
    Brecciated amygdaloid d 3. 326-328
    Trap d 3. 328-343
22. Basic sandstone and fine grained conglomerate d 3. 343 to end.
    Amygdaloidal at top passing into conglomerate; basic sandstones, etc., at 12° ½ from right angles to core. Various pebbles of anorthosite and red rocks.

Calumet drill hole 2. Elevation 490. 640 feet from No. 3. Elevation of profile 532. Depth 505. Dip (10⅝:36) about as usual.

Overburden on the slant (13)

22. Ophite
    Trap d 2. 13-26
    Just a little of that in Hole 3
    Fine grained (1 mm.), bottom black and calcitic
    Nos. 17 to 22 *may* be Eagle River 10 to 16
    Total from No. 16 (104)
23. Conglomerate (Conglomerate 22 of Portage Lake)
    With pebbles of syenite, coarse gabbro, amygdaloid, and real rhyolitic felsite

Calumet drill hole 1. Elevation 520. 648 feet from No. 2. Depth 500. Dip (11:45.) (5700 from Calumet conglomerate foot?)

Overburden on the slant (40)

23. This is all the same conglomerate (22?) with dark basic greenish (180) sandstone, pebbles of felsite and gabbro, hard green trap. Streaks of red shale (280) make an angle of 7° from being at right angles to the hole, other beds more.

Red and felsitic pebbles d 1. 280-505

From this point to the top of the Tamarack No. 5 are about 850 feet unexposed. At Portage Lake there are not 250 feet of traps over No. 19 (which occurs in the Tamarack No. 5 shaft) between it and No. 22, and No. 22 is a very heavy conglomerate above which no traps are known. There is then rather a presumption that this is No. 22 conglomerate, and that to it belongs a good part of the unexplored 850 feet. But I have not thought it wise to assume this or number the beds consecutively (600)

If so in the Eagle River section it would be presumably the heavy beds 17 and 18.

For the character of beds we pass to the description of No. 5 shaft. (See figure and annual report for 1903 and the following notes on the specimens from that shaft and the 29th level crosscut taken by McNair for his specific gravity tests. See also records by Rominger in Volume V.)

If we then supplement the mine sections with the Calumet and Hecla drill work around the horizon of the Kearsarge lode (Section 8) and pass to the record of the Torch Lake and Old Colony we have a section across the range almost without a break which nevertheless shows very little of the Bohemian Group in which the Baltic lode occurs. Other sections compiled by F. Klepetko are given in File 15-8.

While the record of the report for 1903 and Figure 37 is more systematic, there is a certain importance in putting on record my notes on the samples in this part of the section used in McNair's specific gravity tests. The numbers given were those on the paper bags used in collecting the samples, and in a few cases errors have probably crept in.

The belt numbers given in the samples below are those given by the mine captains in sinking the shaft. There was usually two belts to each flow,—one for the trap and one for the conglomerate. Occasionally, however, we differed. They do not, therefore, exactly correspond to the flows and the flow numbers as given for Shaft No. 5 in Figure 37, but they can usually be identified readily, without reference to the Report for 1903, where the exact correspondences are given on pages 254 to 268, by remembering that Conglomerate No. 19 is Belt 4, Conglomerate No. 18 is Belt 7, Conglom-

erate No. 17 is Belt 12. The flow which I have labeled 12 includes Belts 18 and 19. Conglomerate No. 16 is Belt 23. The Greenstone, flow 31, is Belts 50 and 51. The Allouez conglomerate is Belt 52 and the Calumet and Hecla Conglomerate is Belt 84.

NOTES ON SAMPLES FROM NO. 5 SHAFT USED IN SP. GR. DETERMINATIONS.

Belts 6. S. 2. Fine grained with small chloritic amygdules and conspicuous specks changed to iron oxide up to 1-2 mm. which I take to be altered olivine.

Belt 7. S. 1 A. Well-marked conglomerate pebbles, mostly felsitic, very well rounded. One small seam goes through cement and pebbles. The finer matrix seems to be calcite.

Belt 8. S. 9. A fine grained trap with reddish ground and greenish porphyritic feldspar 1-2 mm. upon a matrix of the Tobin porphyrite type.

No. 10. A massive trap. Probably luster mottled, with calcite and laumontite seams.

9. S. 11. Well-marked amygdaloid with pink lined amygdules of calcite. Brown base.

No. 11. S. 51. Amygdaloid and dark, almost black base, and lots of pink amygdules. In certain streaks instead of pink they are green and chloritic, and occasionally the large ones are filled with calcite.

S. 19. No. 11. This seems to be a red to yellowish indurated clay.

S. 26. No. 13. A dark massive fine grained trap with one amygdaloid showing perhaps laumontite in the center, then a marginal agatoid zone and reddish infiltrations in trap adjacent.

No. 16. S. 16. Very well marked amygdaloid with lots of small amygdules with laumontite and calcite. Ground mass dark.

No. 17. Typical ashbed diabase. One joint coated with calcite. Ground is a dark gray and on it lighter gray-green feldspars stand out conspicuously. This is of the melaphyre porphyrite type.

Label erased. May be 16. Dense fine grained trap.

S. 15. Label erased. Amygdaloid with gray ground, and amygdules either large ones of quartz lined with chlorite, or in a few cases with calcite. There are also some small epidote amygdules and a few show some copper. This bag is also marked: "500 label inside".

No. 18. S. 18. Very well marked amygdaloid. Dark brown with calcite. Greenish seams bordered red with pink or pink and white amygdules of extremely minute size at times, and perhaps also altered porphyritic feldspars.

No. 19. S. 14. Has a coarse look owing to feldspar crystals of a greenish color and 1-2 mm. long. There are numerous chlorite specks and spots red with iron oxide are abundant. This is of the general type of the rocks above the Pewabic lode—the Ashbed group.

No. 20. S. 20. Amygdaloid ground, generally greenish gray, occasionally brownish. Amygdules filled with some hard mineral—perhaps quartz.

No. 21. No. 5. Massive trap with calcite.

No. 22. S. 24. A very well marked amygdaloid with a chocolate brown or gray base, and white calcite and pink laumontite amygdules.

No. 24. S. 29. This is a very well marked amygdaloid with lots of amygdules—some entirely calcite, clear and colorless; others pink, but also carbonated, at least in large part. This type of amygdaloid with lots of amygdules seems rather characteristic of this horizon.

No. 26. Laumontite amygdaloid.

No. 27. S. 40. Fine grained massive trap with one feldspar crystal 2-3 mm. long. Another somewhat larger but isolated and not standing out from the ground.

No. 28. This is probably amygdaloidal conglomerate. Red seams and areas of amygdaloid coarsely spotted with pinkish or pink with green bordered amygdules. There is probably quite a little laumontite.

Belt 29. Bottom. S. 6. Shows greenish feldspar decomposed quite conspicuous on a reddish ground.

No. 14. S. 30. Very marked amygdaloid. Much laumontite and the amygdules close together. Dark brown.

No. 30. Top. S. 56. This is probably glomeroporphyritic. There are numerous small amygdules either of dark chlorite or light chloritic stuff and sometimes filled with calcite which also occurs in the seams.

31. Grayish, appearing rather coarse grained, with light greenish feldspar standing out. Dark chloritic blotches. There are also pink seams of calcite and green chalcedonic seams very hard, but probably not datolite, although they are either datolite or chalcedony. This type occurs near the Pewabic lode; also in the Atlantic cross-cut.

No. 12 Center. S. 32. A good many coarse up to 40 mm. fairly well rounded pebbles, and similar fragments which, with calcite, make up the matrix. Very little basic matter. No signs of copper.

No. 32. S. 55. Has a glomeroporphyritic appearance, the feldspars being up to 2 mm. and are reddish instead of the usual green. Amygdules are only partly filled with a nearly white kaolinic substance of green hue, or with a reddish feldspar? Quite clearly belongs to the Ashbed family.

Belt 33. S. 46. Has a coarse appearance, owing to the glomeroporphyritic feldspar which is greenish or pinkish, up to 2 or 3 mm; coarse, with chloritic amygdules; of the same type of the traps near the Quincy mine.

To Belt 34 A. Amygdaloid with open chlorite lined amygdules. The chlorite does not occur in solid radial forms, but in fibers. There are also amygdules of epidote and quartz.

Belt 35. S. 42. A light colored, coarse appearing trap, owing to the plagioclase which is 2-3 mm. long, with chlorite amygdules. It is a lighter greenish gray than the ophites and belongs to a series near the Pewabic lode, just above the Greenstone. In one place is a larger porphyritic feldspar 8 x 2 mm.

Belt 35. S. 12. This is thoroughly massive, and of a coarse feldspathic type like beds just above the Greenstone. There are a few large phenocrysts of feldspar; one 7 x 7 mm. of the oligoclase melaphyre type.

Belt 36. S. 10. Amygdaloid. Dark brown. Studded with small green crystals of feldspar and amygdaloid. Large amygdules are white calcite.

Belt 37. Bottom. S. 54. Fine grained ophite much jointed with occasional crystals 2-3 mm. not standing out from the ground, as they are merely extra long feldspar laths.

Bed 37. S. 14. Light greenish or reddish with numerous little chlorite seams, wavy, and under a lens one can see banded chlorite filling pores. Feldspar quite conspicuous but not strictly of the Ashbed type. Almost a chloritic amygdaloid.

Belt 38. S. 45. Amygdaloid on a reddish ground showing small pinkish or greenish feldspars of the Ashbed type. There are numerous amygdules of light chlorite. Quite different from the delessite of lower belts.

Belt 39. Fine grained. Possibly slightly luster mottled with small chlorite amygdules.

Belt 42. Top. S. 47. A gray-green amygdaloid with amygdules of quartz and

chlorite. A good chance to study the light greenish coating which sometimes occurs.

Belt 44. A. Coarsely amygdaloidal rock grained with calcite amygdules.

Belt 43. S. 52. Like the last sample but much finer and much more full of chlorite amygdules which occasionally are filled with quartz. The ground feldspathic.

Belt 45. Bottom. S. 4. Four or five pieces. Fine grained ophite with occasional chlorite amygdules. In one or two cases the feldspar attains the length of 1-2 mm. but it does not stand up from the ground in the same way as the Tobin porphyrite type.

47. S. 48. A well-marked ophite, and probably quite coarse. Possibly 10 mm. or so.

Belt 46. S. 49. Coarse amygdaloid. Dark reddish ground and amygdules lined with chlorite or filled with a pink and green radiated zeolite or calcite. The pink zeolite seems to be of two types; one of a reddish color, fibrous, changing to green. Hardness 4 minus. The other pink, with copper, less cleavable and unquestionably prehnite. Hardness above 6.

Belt 48. S. 44. Grey amygdaloid. Hard with white amygdules of quartz and some chlorite.

Belt 48. Middle. S. 23. Dark gray with white or chlorite amygdules, and some copper in them. The ground seems to be made up of small red fragments with a green cement in part.

Belt 49. Massive with faint chloritic flecking, but on the whole probably ophite. Much chlorite on joints.

Belt 50. S. 36. Amygdaloid with greenish ground and numerous small amygdules filled with a fibrous radiated, often pink mineral—hard,—thomsonite or prehnite—probably prehnite. Others are filled with laumontite. There seems to be a sort of mottling. The pink prehnite is colored by copper.

Belt 51. Dark massive fine grained ophite, with slickensided chlorite.

Belt 52. S. 34. A conglomerate of felsitic pebbles, mostly pretty well rounded. Some very fine grained; some medium, and one or two with a grain up to 3 or 4 mm. There seem to be a number of dark brown and small feldspar phenocrysts. The dominant type seems to belong to the gabbro or syenite aplite family. I do not notice any with conspicuous quartz, such as is common in the Calumet, while there are a number almost granitic. There are distinct signs of copper.

Belt 53. S. 43. A coarse amygdaloid with calcite amygdules and some red laumontite at one end. There are also seams of a deep maroon, red effervescent, which may be an iron carbonate.

Belt 54. S. 33. A coarse trap with a rather feldspathic look, probably feldspathic ophite, and if so the mottling may be quite coarse. Red specks are distinct. Not much chlorite; some epidote. One or two cavities are chlorite lined and filled with calcite.

No. 55. S. 38. Amygdaloid with dark blue-black back-ground. Calcite and laumontite amygdules.

Belt. 56. Probably fine grained ophite. Massive and free from seams.

Belt 57. S. 39. Amygdaloid with calcite and laumontite amygdules.

Belt 58? S. 17. Fine grained, luster mottled ophite with 1 or 2 chlorite amygdules.

Belt 60. S. 25. Well-marked ophite. Mottles 3 mm. or more.

Belt 61. S. 50. Brecciated amygdaloid with a dark base. Amygdules lined with chlorite and epidote, and sometimes empty. Interstices filled with chlorite. A little laumontite occasionally.

Belt 61. Amygdaloid; dark brown base; white calcite amygdules and reddish, apparently sedimentary matter, in a few cases yellowish with epidote, which seem to indicate transition to amygdaloid conglomerate.

Belt 62. S. 35. Massive fine grained ophite with small chlorite amygdules.

Belt 63. S. 31. Brecciated amygdaloid, with dark red brown amygdaloid and lots of calcite in the interstices; sometimes have pink borders but not always.

Belt 64. Two pieces. Dark fine grained ophite. Red specks rather unusually conspicuous. One joint surface coated with calcite.

Belt 69. A. Brecciated amygdaloid. Dark chocolate red amygdaloid with chloritic amygdules and calcite and laumontite. Chlorite and epidote in the interstices.

Belt 66. S. 7. Well-marked ophite. 2-3 mm.

Belt 68. S. 3. Well-marked ophite with one or two amygdules and a joint covered with calcite and laumontite.

Belt 73. Brecciated amygdaloid with a great deal of calcite and epidote.

Belt 75. S. 36. A brecciated amygdaloid. Dark red amygdaloid with dark specks of epidote, and calcite amygdules and the interstices large and filled with calcite with a border of epidote.

Belt 76 A. Three pieces. Well-marked ophite 2-3 mm.

No. 77. S. 27. Like a belt in a cross-cut. Red amygdaloid fragments in a sort of breccia with epidote and calcite in the interstices. Some calcite is in poikilitic patches.

No. 78 A. Massive fine grained ophite with few chlorite amygdules.

Belt 79. S. 53. Well-marked amygdaloid with large amygdules. On the average larger than S. 52. Filled with calcite and lined with chlorite. Ground dark purplish.

Belt 80. Dark massive ophite, with chlorite on joints.

Belt 85. S. 21. Fine grained; reddish, with chlorite amygdules.

The 30th level cross-cut which was examined by Mr. G. W. Corey and myself running from near the bottom of Tamarack No. 2 shaft continues the section of the Tamarack 5 shaft down below the Kearsarge conglomerate. A drill hole from Tamarack No. 2 shaft reached the Kearsarge amygdaloid in 970 feet.

Notes in 30th level. Tamarack cross-section. 4300 feet down. Strike of lode N. 28° E., of cross-cut 54° E.

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
72.	2-½		1	Coarse amygdaloid with gray trap, hard between 5 and 11 ft.
71.	16		2	Specimens 1, 2 and 3
	22		3	in amygdaloid belt.
	23		4	Next to a little calcite seam dipping 50° to S. E. (i. e., nearly at right angles to dip).
	35	40	5	Coarse amygdaloid.
	43			

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
	52	60	6	Trap.
	61	65	7	Trap.
	67	72	8	Trap.
	76	80	9	Trap, jointed at right angles to bedding.
	84	88	10	Heavy trap, joints dip 70° to N. E.
	93	98	11	All solid trap, ophite probably.
	102	105	12	All solid trap, almost vertical seam and seam perpendicular to it (12x11 feet of trap to amygdaloid).
	112	112	13	
	118	119	14	Laumontite seam.
70.	125	125	15	A few amygdules.
	136	132	16	Gray feldspathic laumontitic.
	140	139	17	Laumontitic, coarsely amygdaloid.
	147	145	18	Laumontitic amygdaloid.
	151	149	19	Marked hard gray and white amygdaloid.
	153	152	20	Greenish epidote altered.
	159	155	21	First class amygdaloid.
69.	163	158	22	Trap fine grained.
	170	162	23	Trap fine grained.
	176	167	24	Trap fine with a calcite seam.
	184	175	25	Still massive fine grained trap.
	188	185	26	Same.
	191	192	27	
68.	199	197	28	Amygdaloid, gray and white, wet.
	203	200	29	Amygdaloid, gray and white, wet.
	207	204	30	Amygdaloid.
	211	205	31	Fine grained red trap, a laumontite seam running to W. dips S.
	216		32	Amygdaloid conglomerate.
	220		33	Amygdaloid conglomerate.
	227		34	Amygdaloid conglomerate.
	231	220	35	Amygdaloid conglomerate.
	236		36	Amygdaloid conglomerate.
	240		37	Amygdaloid conglomerate (at 239 trap).
	246	235	38	A well-marked amygdaloid conglomerate with red sediment.
67.	253	237	39	Trap.
	262		40	
	271		41	Amygdaloid, pink and white.
	280	280	42	Red trap.

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
	288	280	43	Red trap.
	293	293	44	Red trap.
	301		45	Coarse amygdaloid.
	309		46	Marked amygdaloid, coarse gray and white, then amygdaloid with small amygdules, laumontite.
66.	318	318	47	Markedly clasolitic (with red seams of sediment).
	328		48	
	343		49	
	357	357	50	Epidote, spotted and getting amygdaloidal.
	370		51	Coarse amygdaloid, but mainly trap.
	384		52	Amygdaloid.
				Winze, which were generally sunk in amygdaloid I am told for ease of working. The water from the winze floats the urinometer above the bottom of the scale=1.060 plus.
	401	401	53	Amygdaloid poor.
65.	414	414	54	Brecciated marked amygdaloid just above contact.
	421	421	55	Near top of amygdaloid.
	422	422	56	Fine-grained amygdaloid.
	428	428	57	Sparsely amygdaloid.
	434	434	58	
	448	448	59	Trap with irregular jointing.
	462	462	60	Coarsely spotted with amygdules.
	478	478	61	Slickensides and marked irregular amygdules.
	490	490	62	
	494	494	63	Massive trap.
	509	509	64	Coarse amygdaloid skeined parallel to the bedding but not the contact of a new flow.
	525	525	65	Trap.
	544	544	66	
	559	559	67	
	575	575	68	
	590	590	69	
	605	605	70	
	625	625	71	
	641	641	72	Coarse amygdaloid begins.
	656		73	

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
64.	668		74	
	675		75	
	683		76	
	697		77	
	700		78	Kearsarge Cg. Dip 35° L. or 35°½ McNair.
63.	702		79	Two feet of fluccan on top of Kearsarge conglomerate, decomposed upper bed, dip of this fluccan 37°½ to 36°.
	708		80	Trap. Surveyor's plug 10 at 710.
	724		81	Massive trap.
	731		82	
	741		83	The same, laumontitic.
	749		84	Somewhat amygdaloid.
	756		85	Trap just beyond a seam parallel to the dip.
	762		86	Trap, close to laumontite seam.
	769		87	Laumontitic seam dipping 42°.
	773		88	Trap, marked massive.
	780		89	Trap, marked massive.
	786		90	Cross-course to the North dipping 59° to the E.
	792		91	
	799		92	Trap with occasional coarse amygdules.
	804		93	Trap with occasional coarse amygdules.
	813		94	
	821		95	
	834		96	Well-marked amygdaloid.
62.	841		97	Trap with joints parallel and perpendicular to the bedding.
	850		98	
	858		99	
	876		100	
	884		101	Very massive.
	892		102	Calcite seam dipping E. in massive trap.
	900		103	All massive trap.
	906		104	All massive trap.
	914		105	All massive trap, flat seams.
	922		106	All massive trap.
	929		107	Amygdaloid in spots.
	936		108	Trap.
	943		109	Trap.
	951		110	Massive trap.
	958		111	Coarse amygdaloid.
	965		112	Amygdaloid showing amygdules elongated parallel to the bedding.

Belt.	Corey's distance from S. E. of My. shaft T 2.	Specimen No.	
61.	973	113	
	979	114	
	985	115	
	992	116	
	996	117	Poorly marked amygdaloid.
	1004	118	
	1010	119	
	1016	120	Columnar jointing perpendicular to the bedding.
	1022	121	Massive trap all along to Sp. 127.
	1028	122	
	1036	123	
60.	1043	124	
	1049	125	
	1055	126	
	1061	127	
	1069	128	
	1077	129	
	1083	130	
	1087	131	Massive. Surveyor's plug P. B. near it.
	1094	132	
	1098	133	
	1107	134	Still massive, with a big spot of calcite.
	1115	135	Still massive. (The roof caves.)
	1121	136	
	1127	137	
	1134	138	
	1139	139	Still massive.
	1144	140	
	1150	141	
	1156	142	Amygdaloid.
	1161	143	Red and white amygdaloid, fairly well developed.
59.	1166	144	
	1172	145	Trap.
	1177	146	Trap.
	1184	147	Trap.
	1191	148	Trap, with calcite.
	1196	149	
	1203	150	Contact well-marked.
58.	1206	151	Trap.
	1212	152	Trap.
	1217	153	Trap.

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
	1224		154	Trap.
	1228		155	Trap.
	1233		156	Trap.
	1238		157	Trap.
	1246		158	Trap.
	1251		159	Trap.
	1256		160	Still massive trap.
	1263		161	
	1266		162	
	1271		163	
	1279		164	Marked red and white amygdaloid just below contact.
57.	1283		165	
	1289		166	
	1294		167	Trap.
	1300		168	Very coarse amygdaloidal spots (pseud-amygdaloid?)
	1308		169	
	1313		170	
	1320		171	
	1326		172	
	1332		173	
	1337		174	
	1346		175	
	1354		176	
56.	1362		177	
	1371		178	Black chloritic trap.
	1377		179	
	1384		180	
	1389		181	
	1397		182	Trap.
	1404		183	
	1411		184	Coarse ophite, augite patches 3 to 4 mm. across.
	1417		185	
	1424		186	
	1430		187	Seam parallel to cross-cut, i. e., to the drift.
	1437		188	
	1443		189	
	1450		190	Trap.
	1457		191	Still seamed parallel to the cross-cut (S. 40° F.)
	1464		192	

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
	1471		193	Trap still.
	1478		194	Trap.
	1484		195	Trap.
	1491		196	Trap.
	1497		197	Trap.
55.	1502		198	Trap.
			199	
	1509		200	A seam of copper and prehnite is parallel to the bedding or steeper.
	1518		201	
	1524		202	Surveyor's plug 18.4.
	1530		203	Amygdaloid.
	1539			
	1544		204	
	1547		205	Coarse amygdaloid.
	1554		206	
	1564		207	
	1568		208	
	1575		209	Between 209 and 210 is a drift on the Osceola amygdaloid.
	1594		210	
	1599		211	
	1607		212	
	1621		213	
	1630		214	
	1645		215	
	1654		216	
	1661		217	
	1666		218	Timbered.
	1672		219	
	1679		220	
	1689		221	
	1698		222	Massive trap.
	1706		223	Amygdaloid.
	1714		224	
	1721		225	
	1729		226	
	1736		227	
	1742		228	
	1751		229	
	1761		230	
	1769		231	
	1777		232	
	1785		233	Well-marked amygdaloid.

Belt.	Corey's distance from S. E. of My. shaft T 2.	Specimen No.	
	1794	234	Here is a watering spot from which the sample analyzed by F. B. Wilson was taken. See Chapter VII.
	1800	235	
54.	1809	236	
	1816	237	Trap.
	1824	238	
	1831	239	
	1836	240	
	1843	241	
	1851	242	
	1861	243	Surveyor's plug.
	1869	244	Winze.
	1870	245	
	1887	246	
53.	1893	247	
	1899	248	
	1907	249	
	1915	250	
	1922	251	
	1929	252	Irregular trap.
	1935	253	
	1942	254	Irregular trap.
	1950	255	Massive trap.
	1956	256	
	1963	257	
	1969	258	
	1976	259	
	1987	260	
	1994	261	Somewhat seamed parallel to the bedding.
	2001	262	
	2007	263	
	2016	264	
	2024	265	
	2031	266	
	2037	267	
	2047	268	
	2054	269	
	2059	270	
	2068	271	
	2074	272	
	2081	273	

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
	2088		274	Amygdaloid.
	2098		275	
	2104		276	
	2112		277	
	2119		278	
	2124		279	
	2137		280	
	2143		281	
	2150		282	
	2169		283	
	2177		284	
	2185		285	
	2192		286	Much brecciated, no slips of importance beyond to 303 I think.
52.	2200		287	
	2208		288	
	2218		289	
	2227		290	
	2236		291	
	2244		292	
	2256		293	
	2264		294	
	2273		295	
	2283		296	
	2292		297	
	2303		298	
	2312		299	
	2324		300	
	2336		301	
	2343		302	
51.	2360		303	16 feet to center of drift,—a level on the C. & H. lode.

The section is continued by a drift from the 29th level over to Tamarack No. 5 shaft. This is above the Calumet and Hecla Conglomerate No. 13. It may be noted how copper collects on the low parts of the roof of this level and makes a green copper carbonate stain which shows that it has copper in solution. According to other green streaks of altered copper the copper occurs in the conglomerate in streaks parallel to the bedding. As this drift is at a considerable angle with the direction of the dip I have noted whether the specimens were taken from the left (S. W.) side by L. or the right (N. E.) by R.

	705–3		304	Distances referred to plug specimens numbered 304-308 are all from the C. & H. conglomerate. The copper comes first in the cement. Then there is a halo bleached

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
				in the conglomerate pebbles, then the outside turned to copper.
	705–2		305	
	16		306	
	25		307	
	31		308	
	35		309R	Rather sandy.
50.	41		310R	At iron pin, hanging amygdaloid with large patches of calçite with red border, also clear amygdules.
	47		311R	Jointed dip with contact.
	54		312L?	Marked contact dip 32°-36°. Very clear, sandy? just above it.
49.	61		313R	Just above contact on right.
	67		314R	Ophite.
	75		315R	Ophite growing coarser.
	81		316R	Ophite growing coarser.
	87		317R	Ophite growing coarser, cupriferous.
	94		318R	Ophite growing coarser.
	99		319L	
	106		320L	
	121		321L	All massive trap.
	129		322	All massive trap.
	138		323	
	146		324L	A seam crosses the drift with a steep dip running nearly parallel to the strike.
	156		325L	
	168		326L	Spotted.
	177		327L	
	188		328L	
	199		329L	Chloritic seams abundant.
	206		330L	Epidotic altered.
	221		331L	
	232		332L	
	233		333L	Genuine amygdaloid, damp.
	249		334L	Seamed.
			335	
	262		336?	
	270		337R	Marked green and white amygdaloid
	279		338R	Spotted clay seam.
	289		339R	
	299		340L	
	309		341L	Calcitic rock soft.

Belt.	Corey's distance from S. E. of shaft T 2.	My.	Specimen No.	
48.	318		342L	Fine grained ophite.
	335		343L	2 to 3 mm. patches of ophite.
	345		344L	
	354		345	
	366		346R	Coarse ophite.
	376		347R	
	388		348	Massive.
	397		349L	Bedding joints marked.
	411		350R	Fine grained massive.
	425		351R	Broken up.
	436		352	
	451		353L	Massive.
	464		354L	Veined.
	479		355	Surveyor's plug 9, Trap.
	491		356	Surveyor's plug 8.
	501		357R	Wet amygdaloid.
	520		358R	Red and green amygdaloid.
47.	530		359L	Looks massive.
	542		360L	Coarse.
	548		361L	Coarser.
	555		362R	
	571		363R	Ophite with 3 mm. patches.
	583		364R	Coarser.
			There is no 365.	
	595		366L	
	606		367	
	618		368L	Joints parallel to bedding.
	625		369L	
	638		370R	Ophite patches 1 to 2 mm.
	648		371R	Fine. A slickensided face striking N. dips to the W. and makes an angle of about 30° with the course of the lode. The striations incline to the N.
	659		372R	Coarser?
	668		373R	Coarser?
	680		374R	Coarser?
	690		375R	
	703		376R	Decreasing? irregularly jointed.
	712		377	Plug 5, water begins.
	722		378	Slickensided, light green. In this part of the section there are on top of the traps and fading into them often greenish light amygdaloids.

Belt.	Corey's distance from S. E. of shaft T 2.	My. Specimen No.	
	736	379R	Looks like pink and green castile soap.
	751	380	
	761	381R	Amygdaloid, decomposed, wet, both sides.
46.	776	382R	Dry.
	788	383R	
	800	384R	
	813	385R	
	825	386R	
	835	387R	
	841	388	
	851	389	Marked amygdaloid.
	865	390	391 to 395 are in the No. 5 shaft plat.
	874	391	
	895	400	Face of drift.

DETAILED NOTES ON THE SAMPLES FROM CROSS-CUT USED IN PRESIDENT McNAIR'S SPECIFIC GRAVITY TESTS.

Belt 72. 1. Ophitic trap-luster mottled, perhaps 2 mm. Epidote seams. Amygdaloid spots. Epidote border and sometimes a quartz center. The band of greenish, radiated, cleavable zeolite is perhaps laumontite. The main mass of the trap, like ophites generally, shows greenish chloritic or epidote spots; rusty brown specks which I attribute to altered olivine, which are not largely conspicuous; faint, light greenish indications of feldspar laths and a dark ground which is presumably an augite. This is a general description of ophites and will be understood unless special notes are made. No. 1 will ordinarily be classed as trap.

Belt 71. 2. Amygdaloid with dark chocolate red base. The amygdules have a border of blue-green chlorite or yellow-green epidote. The center is light colored, white calcite. Between these there is a pinkish layer, so far as tried non-effervescent—soft and friable and I presume laumontite.

Hereafter white minerals of the calcite cleavage will be called calcite; the light pinkish friable minerals, laumontite; yellow-green, epidote; and bluish green, chlorite, unless there is some special mention. The walls of the amygdules are well defined and often rounded, being clearly bubbles.

3. Ophite, mottles not over 2 mm. with a small seam of laumontite and calcite amygdules at one side. Both are in a previous specimen. There is occasionally a spot of the light greenish color which seems to shade into the laumontite and might be taken for prehnite if it were not too soft. 3 pieces.

4. Probably an ophite. The feldspar laths are somewhat more conspicuous on certain surfaces and the brown-red alteration more extensive and minute laumontitic seams a fraction of a mm. can be seen in the

interstices of the ground mass. There is also considerable white material (calcite) pervading the ground mass. The alteration of reddish and greenish spots is more conspicuous. This is an ophite.

5. Ophite. Luster mottling may be 3-4 mm. One side is covered with laumontite and the quartz with epidote. There is also one large amygdule filled with laumontite and quartz, with epidote and chlorite in the border. This should be counted as a trap and the amygdules are such as are likely to occur only sporadically in the trap.

6. Ophite. Mottles perhaps 2-3 mm. Some surfaces coated with slickensided chlorite. 2 pieces.

7. Ophite. Massive although there are some irregular chloritic seams.

8. Probably ophite. More decomposed feldspar about .6 mm. There is a good deal of calcite in irregular seams. It contains some copper which has turned slightly green to carbonate.

9. Massive trap, much reddened and on one side coated with shining irregular face of iron oxide. Next to a little seam of laumontite there is the crystalline form. While it is probably ophite the mottles cannot be identified in the hand specimen. Feldspars may be .8 mm.

10. Ophite. Massive and broken up; rather smooth joints. One joint is covered by patches of calcite which are not to be mistaken for luster mottling. This is probably about 3 mm.

11. Ophite. Luster mottles probably about 2 mm. Has small irregular calcite seams.

12. A good deal seamed with calcite and a little laumontite. Mass of the rock shows considerable epidote. Mottling is probably about 2 mm.

13. Ophite. In one place there is a little mottling of secondary calcite but the genuine augitic mottling appears to be about 1½ mm.

14. Ophite. Crossed by an irregular quartz stringer with epidote border. Luster mottling is about same size as 13. Is well-marked. One side of the specimen is coated with pink laumontite; the other with a soft gray stuff that looks like mud or varnish, being a shiny coating.

15. Ophite. A good deal decomposed. Laumontite in little seams runs all through especially in certain lines. Large irregular epidote quartz pseudamygdules. In these there is red matter which may be copper oxide or iron oxide—a reddish band rather extra decomposed may represent flow line. The ophitic mottles probably between 1 and 3 mm.

16. Much decomposed. Very coarse mottling—is due to patches of calcite. The mass of the rock is uniformly flecked red or green. It is traversed by little irregular seams of fine grained red sediment (clasolites). These clasolites are probably considerably lighter and may affect its gravity.

17. Ophite. Mottles 1-2 mm. probably, but the whole rock much decomposed. There is a good deal of reddish brown clasolitic matter in it. It is also more or less epidotic. Number of specimens.

18. Ophite. With one or two amygdules. One shows a quartz border very sharply defined and one side a laumontitic center, the farther part of the amygdule not being so clear against the ground mass.

19. Genuine amygdaloid. Amygdules 3 mm. more or less. Sometimes lined with radiating chlorite and then empty; also with quartz;

epidote often occurs at the border and the epidote specks in the mass seem to be rather pseudamygdules, the epidote forming more at the expense of the ground. The ground mass is the usual red and white flecked of the ophite, but the mottling is now probably not 1 mm. This is the first genuine amygdaloid.

20. Probably at or near contact. A breccia of a very fine grained trap and epidote and quartz masses and fine grained amygdaloid in a reddish clasolitic matrix. This may be from a scoriaceous or amygdaloidal conglomerate, but it might be only a seam in the amygdaloid.

Belt 70. 21. Similar to 20 with fragments of amygdaloid. Apparently more than one kind; at least there are two different classes. There is a greenish gray amygdaloid, then there is a dark reddish amygdaloid. Amygdules are calcite. Brown to red matrix shows line of sedimentation. In some parts it is quite epidotic.

22. Well-marked ophite. Quite fresh looking and apparently not very fine grained with coarse chloritic flecks. This is rather dark colored.

23. A massive fine grained trap, covered with chlorite on four faces, the striations running not very systematically. Two faces are smooth; two faces are tortuous.

24. Similar to 23 with chloritic joints also fine grained.

25. A similar ophite. Fresh looking; fine grained; not so prominent chloritic joints. Mottles possibly 1-2 mm.

26. Same with slickensided chlorite on joints; reddened; slightly amygdaloidal with chloritic spots.

27. A small, similar reddened trap with little spot of laumontite and calcite one end.

28. Three or four pieces. More amygdaloidal with more laumontite and calcite. Amygdules are small and grade into secondary specks.

29. Well-marked amygdaloid; fine grained, dark maroon with occasional porphyritic feldspars up to 1 mm. long. Amygdules of calcite and laumontite, and a little epidote at the margin. Smooth walled. There seem also to be secondary epidotic specks, and there are also seams coated with calcite, laumontite, chlorite, and a little epidote.

30. A number of pieces. Fine grained, dark maroon. Some amygdules and secondary specks of laumontite and larger aggregates of calcite.

?Belt 69. 31. Two or three pieces. Somewhat brecciated and of amygdaloidal conglomerate type, made of black fragments mixed together and seamed by calcite, but no sedimentary matrix like that in Beds 20 and 21 noticeable. This is more probably merely a shattered bed at the top of the amygdaloid.

32. Three or four pieces. Dark colored with much calcite infiltration seams, also laumontite on fissures. Brecciated.

33. Dark; full of calcite and laumontite similar to the last.

34. Shows mixture of red sediment although fine grained, compact trap fragments with one porphyritic feldspar 2-3 mm. long. Twinned and chloritic amygdules.

35. Two pieces and more. Fragments of fine grained trap are imbedded in the sandy matrix in which small cavities of laumontite and calcite occur. There are also signs of crushing. While on the whole it seems rather more likely that this is an amygdaloid conglomerate, we can not say that it is not crushed clasolitic amygdaloid or trap.

36. Is mainly sediment; red; and under the microscope appearing somewhat sandy. There are striated slickensided faces and some fragments of trap imbedded.

37. Three pieces. Amygdaloidal with seams of sediment. Here the sediment appears distinctly intrusive into the amygdaloid while in 36 the amygdaloid is in the nature of fragments in the sediment. The amygdaloid is nearly black with small amygdules of calcite.

38. Amygdaloid; appears somewhat ophitic. Amygdules irregular and laumontitic and larger ones with calcite centers.

Belt 68. 39. A blotched somewhat ophitic trap with clasolitic irregular seams; also crossed by a stringer of calcite.

40. Fragments of amygdaloid imbedded in a brown sediment, sometimes yellowish, epidotic and distinctly stratified and sandy. The fragments appear, however, to be of the same kind and much like the specimens last described with blotches of epidote and laumontite.

41. Rather decomposed, fine grained trap with a lot of clasolitic seams or sediment matrix to fragments. There seems, however, to be a certain fitting of the fragments together so as to indicate that they were once part of a continuous mass.

42. Like 41. Full of red clasolite matter, and not any very defined amygdules. The amygdules are small and there are also decomposition patches.

43. Is mainly clasolitic sediment. Should give a pretty good idea of the specific gravity of that sort of stuff, but I doubt if it is a fair sample of any regular bed. There is some amygdaloid clinging to it.

44. A mixture of rather coarse, sandy, clasolitic stuff with a dark, fine grained, not very amygdaloid trap.

45. Brecciated amygdaloid with the interstices filled with laumontite and green calcite. There is also epidote on the edges. The laumontite in some places appears to become green, but I think it is due merely to mixture with green calcite which is unusually well marked.

46. Well-marked amygdaloid, rather coarse grained. Amygdules of laumontite and quartz. Rather small.

Belt 66. 47. Well-marked ophitic trap with mottles not over 2 mm. and amygdaloid spot in one corner, and calcite seam on opposite face. The whole mass of the trap seems to be decomposed and have minute red, probably laumontitic specks.

48. Ophite. Fine grained with small clasolitic streak, which seems itself to have somewhat amygdaloidal texture but the amygdules are not sharp. The main trap is full of small amygdules largely laumontitic.

49. Two or three pieces. The small pieces are fresh looking ophites although there are little calcite stringers traversing it and upon close examination there is an unusual amount of chloritic alteration. The main base is covered all over with a white coating probably due in some way to the specific gravity treatment.

50. Apparently almost solid epidote up to a little laumontitic seam beyond which the trap is not quite so much decomposed and the structure can be somewhat made out. It was probably moderately ophitic. There appears to be more chlorite and less epidote in this part.

51. Ophite. Probably about 2-3 mm. A few specks of laumontite and calcite and also one appears to be solid laumontite, the alteration throughout the ground mass to iron oxide being unusually conspicuous.

52. Somewhat amygdaloidal but still coarse grained rock, probably having a mottling of 2 mm.

53. Well-marked, fine grained amygdaloid with white amygdules of calcite, numerous bright red specks on a gray-green ground with little epidote. This should be near the top of a flow.

Belt 65. 54. Ophite with calcite and laumontite amygdaloid spots. Rather inclined to be pseudamygdaloid, but there are a few small genuine amygdules. Red specks of iron oxide on the ground.

55. Rather fine grained amygdaloid with small amygdules, and also large patches of laumontite and calcite. Chocolate ground mass.

56. Fine grained, filled with laumontite and chlorite; much decomposed. The most typical amygdaloid along here is No. 53.

57. Decomposed laumontite amygdules. They are much saturated with laumontite. Amygdules comparatively scarce.

58. Like 57. Full of laumontite with large patches of amygdules of calcite. 56, 57, and 58 are practically similar.

59. A decomposed ophite. There is a good deal of epidote, and the base has a brown and green mottling of about 2-3 mm.

60. Ophite. Probably 2-3 mm. with occasional large amygdules of calcite. Some laumontite in cores. Amygdules are somewhat bordered with chlorite and laumontite.

61. This appears like a very fine grained trap near the bottom of the bed. There is some epidote and a few blotches of calcite and quartz.

62. Two pieces. Fine grained; very epidotic with blotches of quartz.

63. Somewhat laumontitic trap 1-2 mm. with pores filled with laumontite.

64. This has a few amygdules clearly defined of calcite. The feldspar is rather extra long—2-3 mm., and there may be an approach to a doleritic texture.

65. Apparently fine grained, dark chocolate red with 2-3 mm. feldspar and some amygdules of quartz and chlorite.

66. Quite coarse and feldspathic, the feldspar laths being conspicuous and there are also spots of iron oxide. This is sometimes in the interstices of the feldspar and after augite; perhaps also after olivine. One face is covered with calcites which are striated with slickensides.

67. Coarse, massive, feldspathic ophite. This is almost the first in which the mottling can be determined with any real precision. It is here up to 4 mm. across. Usually about 3 mm. Is a well-marked feldspathic ophite.

68. Same type. Mottles very vague.

69. Same type, getting coarser, but the mottling is too vague to measure accurately. There is a little calcite seam.

70. Same still coarser. At one end a seam of calcite. Dominant appearance of the rock is gray with reddish specks.

71. Seems to be getting finer. There are a few amygdules of calcite.

72. About the same—little darker. One chlorite amygdule.

Belt 64. 73. Felsitic Kearsarge conglomerate pebbles of dense feldspathic porphyry. Coarser grained rocks of the gabbro aplite type also of quartz porphyry make up the mass of the rock down to the very small fragments which are still felsitic or broken out quartz and feldspar. The last matrix is calcareous. There is very little basic material and no copper apparent. Hardly any epidote or any secondary mineral but calcite.

74. Another specimen of the conglomerate which has, however, one distinct fragment as much as 13 mm. long of some decomposed basic rock, probably amygdaloid. Plenty of quartz porphyry. Matrix of small fragments—little but calcite secondary.

75. Same as 74. Lots of quartz porphyry. One or two streaks of dark stuff like serpentine.

76. Same conglomerate. Matrix grayer but more epidotic. The pebble mainly near quartz porphyry with feldspar crystals 16 mm. long, and quartz bi-pyramids something like 5 mm.

77. Some conglomerate. Felsite pebbles generally quite small—one or two pebbles—one or two dark pebbles up to 37 mm. long. These have a dark soft matrix and crystals of feldspar that stand out and show terminal faces. Probably belong in the trachyte or andesite family. Mr. J. L. Nankervis has given me a similar pebble from the C. & H., largely changed to copper, with a matrix very soft so that the Karlsbad twins can easily be picked out. Mr. Jos. Pollard has Karlsbad twins picked out probably from a similar rock. The cement is calcite and epidote.

78. Similar conglomerate, with various kinds of porphyry. The matrix of epidote and calcite and one or two green serpentine grains only a few mm. in diameter.

79. Soft grayish green clay. This appears to be decomposed and crushed trap.

80. Fine grained, reddish trap, with a few coarse chloritic amygdules. These are dark green at the center, and seem to bleach to a lighter color at the margin. They do not seem at the center to have the usual fibrous structure of delessite. In part of the specimen the seams are specked with calcite.

81. Probably a fine grained ophite. 1-2 mm. with much laumontite in specks throughout, and the same covered with patches of calcite.

82. Massive ophite. Small amount of laumontite on seams.

83. Ophite. With a few scattered calcite amygdules surrounded by laumontite or chlorite. The mottles may be 3 mm. across. It is not plain.

84. Fine grained amygdaloid with hard amygdules and quartz; very little epidote; some pinkish material. This must be near a contact.

85. Massive ophite. Mottling not over 1-2 mm. One seam face covered with laumontite; another with slickensided chlorite.

86. Ophite. Rather fine grained. One face covered with laumontite —just a film.

87. Ophite; somewhat coarser. One seam covered with a white coating of small granular crystals. Are they analcite? They do not effervesce in acid, and seem to be reasonably soft.

88. Massive ophite. Mottles 3-4 mm. Occasionally prismatic forms of augite 7 x 2 or 5 x 2.

89. Another coarse ophite. One face covered with laumontite. Mottles distinct and about 4 mm.

90. Well-marked ophite. Mottles about 3 mm. One face covered with laumontite, pink and white.

91. Ophite. Mottling faint—about the same as heretofore. Perhaps somewhat more chloritic.

92. Coarse ophite. Mottles about 3-4 mm.

93. Medium grained ophite. Two faces making an angle of 105° covered with laumontite. Mottles 2-3 mm.

94. Ophite. One face covered with laumontite. Mottles somewhat finer. 2-3 mm.

95. Massive ophite about the same grain.

96. Slightly amygdaloidal with blotches of epidote, radial chlorite, calcite.

Belt 62. 97. Distinctly finer but of massive trap. The chlorite on seams and in smaller chlorite amygdules. I should not have taken 96 to be amygdaloid top, but as my notes say there is a well-marked amygdaloid and finer grain is distinct, it had better be counted.

99. Massive ophite. Curved faces covered with slickensided chlorite. Mottling 2-3 mm.

100. Massive ophite. Two faces covered with a dark serpentine or chlorite. Mottling is less than 4 mm. Perhaps nearly 5.

101. Many surfaces covered with slickensided chlorite. Mottling 5 mm.

102. One face covered with laumontite; one with chlorite. Mottles 5 mm.

103. Massive ophite. Mottles 5-6 mm.

104. Coarse ophite. Mottles 6 mm.

105. Coarse ophite. Mottles quite conspicuous. 4 mm? The luster patches are a little smaller than the general effect of the mottling perhaps.

106. Ophite. Mottles 3-4 mm.

107. Massive ophite. There are some little white specks but they are not sharp walled and do not appear to be genuine amygdaloids. They have a fibrous structure and are hard. Probably prehnite or thomsonite. May be a little copper. This is not a compact amygdaloid.

108. Well-marked ophite. One face covered with laumontite. Mottles about 3-4 mm.

109. Well-marked ophite. Dark. Mottles about 3 mm. and very plain—colored and dark and full of serpentine or chlorite. Brownish inge of the augite is faintly visible.

110. Well-marked ophite. Mottles about the same—3-4 mm. This piece seems to show no secondary minerals and seams.

111. Well-marked ophite. Small speck of native copper and little stringer of calcite, mottles being 2-3 mm. This is not properly amygdaloid.

112. Luster mottled 2-3 mm. with amygdules of pink copper-bearing prehnite.

Belt 61 not independent. 113. Massive ophite. 2-3 mm. with one or two amygdules of pink prehnite.

114. Massive ophite. Rather decomposed with a few chloritic amygdules and one or two of prehnite. Mottles not plain but probably rather coarse.

115. Massive, fine grained ophite with numerous chloritic blotches, and one showing calcite, epidote and copper in the center beside a chloritic rim.

116. Fine grained ophite. Not over 1 mm. Few chlorite amygdules. There is a confusion here between samples and records.

117. Well-marked amygdaloid. Brecciated and perhaps amygdaloidal conglomerate. A cement of calcite; prehnite; trace of copper.

This is peculiar in that there is a border of earlier, slightly brownish calcite on top of which occurs a light greenish mineral which I take to be prehnite. This is evidently close to a contact.

118. Fine grained, brecciated, decayed amygdaloid with epidote and calcite.

119. Fine grained well-marked ophite. Mottling not over 1½ mm.

120. Fine grained massive trap. A little laumontite in one seam.

121. Fine grained massive ophite. Little stringer of laumontite and calcite. Mottles less than 2 mm.

122. Fine grained ophite with a few coarse amygdules of epidote, and quartz and smaller ones of chlorite. Epidote is very yellow and has distinct needles.

123. Trap similar to 122, but with chloritic amygdules. These often show a fibrous layer of chlorite with a hollow center in which it has grown. The ground is chocolate brown.

124. Fine grained, well marked amygdaloid. Probably near contact with porphyritic feldspar laths 1 mm. or so long.

125. Massive trap, fine grained. Laumontite and chlorite seam.

126. Dark ophite. Mottles well-marked but not more than about 1½ mm. Very fresh looking.

127. Two pieces. Ophite about 2-3 mm. Chloritic slickensided joints.

128. Massive ophite. 2½ mm.

129. Massive ophite. 2-3 mm. One seam covered with soft white effervescent stuff in pearly coats—I presume calcium carbonate. Is it possibly magnesium carbonate?

130. Massive, luster mottled ophite 3 mm.

131. Massive ophite 1-2 mm.

132. Massive ophite about same grain. One face heavily coated with striated chlorite and calcite.

133. Massive ophite. 2 mm? One seam coated with striated chlorite.

134. A rather fine grained ophite with 2 or 3 parallel seams.

135. Rather fine grained ophite. On one side a seam 2 mm. thick of chlorite, on the other 10 mm. thick of calcite and chlorite. The calcite shows pressure banding very finely.

136. Apparently still ophite, much decomposed and seamed chloritic.

137. Fine grained with chlorite amygdules.

138. Apparently not very coarse ophite. Rather decomposed with bluish chlorite on some places. Mottles probably 1-2 mm.

139. Massive ophite. Mottles probably not over 1-2 mm. Red and green ground. Somewhat coated with chlorite, laumontite, etc., on faces.

140. Ophite not over 1-2 mm., with fine chlorite amygdules.

141. Ophite fine grained with frequent chloritic blotches.

142. Ophite. Mottled and with vague amygdules.

143. Fine grained, red matrix, and one end well-marked amygdaloid spot filled with chlorite and calcite.

Belt 59. 144. Fine grained ophite. About 1 mm.

145. Two or three pieces. Massive ophite about 2 mm.

146. Ophite with chlorite and laumontite near face. About same grain.

147. Ophite, fine grained, with chlorite amygdules.

148. Well-marked amygdaloid with a grayish-brown base, fibrous, greenish, hard prehnite in irregular amygdules. Little epidote older than the prehnite. Probably a little copper.

Belt 58. 149. Fine grained ophite, with slickensided chlorite seams.

150. Ophite. 1-2 mm. with a face heavily slickensided with chlorite.

151. Ophite. 2½ mm. Some faces heavily slickensided with chlorite. The direction of the striations comes together on two faces sloping toward each other.

152. 3 mm. ophite, with one face having slickensided striations.

153. Massive ophite about same grain, with a seam of slickensided chlorite 8 mm. thick. Is it not possible that in knocking off small specimens there is a tendency to get too much of this chloritic seam material?

154. Well-marked massive ophite. Mottles 3-4 mm. One face heavily slickensided with chlorite.

155. Fine grained; uniform in color; apparently decomposed mass of quartz and chlorite with seams of quartz and prehnite containing quite a little native copper.

156. Marked coarse ophite. Mottles 3-5 mm.

157. Marked coarse ophite. Mottles 4-5 mm.

158. Finer ophite. Mottles 4-5 mm.

159. More feldspathic looking. Lighter colored. Mottles about 4 mm.

160. Marked ophite. Mottles about 4 mm.

161. Marked ophite. Mottles somewhat lighter. About 5 mm., or even 6 mm. long. Tend to be prismatic. In one side of the specimen is a little seam of cupriferous pink prehnite and chlorite.

162. Marked ophite. Mottles about 3-4 mm. One side heavily slickensided with chlorite.

163. Marked ophite. Mottles 3-4 mm.

164. On one side ordinary laumontite. Ophite with mottles perhaps 3-4 mm. Transition can very easily be seen through the doleritic texture which occupies about ¾ of the specimen. In this the feldspar is much coarser. There are porous irregular blotches filled with epidote and calcite, around which the green appears to be finer, but probably not so. The feldspars are something like 3 mm. long. The augite is still probably coarse. Along the contact between the doleritic texture and the regular ophite there is an unusual amount of chlorite, but there is no sharp line or growing finer of either texture. In fact the augite patches in the doleritic may be seen, but owing to the feldspar they are not so conspicuous. This doleritic streak seems to have been used to divide belts.

Belt 57. 165. Coarse ophite. 3-5 mm.

166. Ophite. 2-3 mm.

167. 2-3 mm.

168. Ophite, with few chloritic amygdules. 2-3 mm.

169. 2-3 mm. A few chloritic amygdules. One shows a fibrous chlorite at the margin, and then solid chlorite at the center. Mainly delessite.

170. 1-2 mm.

171. Fine grained ophite.

172. Fine grained ophite with chloritic spots, probably arranged in flow lines.

173. The parting due to the chloritic spots quite well marked, which probably indicates the flow or direction of dip. Both massive and radiate chlorite occur.

174. Fine grained ophite with few chloritic specks.

175. Fine grained ophite with chloritic coated face.

176. Finer grained trap. Seam coated with chlorite and yellow earth.

177. Fine grained ophite. About 2 mm. mottling. Chlorite seams.

178. Ophite. 2-2½ mm. With chlorite seams and dark color.

179. Ophite. Mottles 2½-3 mm. One face is covered with slickensided chlorite.

180. Marked ophite. 1-2 mm. One face is very finely polished and slickensided. Another is studded with chlorite and calcite in patches.

181. Very dark ophite; patches about 3 mm.

182. Lighter ophite; patches 3-4 mm.

183. Coarse ophite; patches from 4-5 mm.

184. Coarse ophite, with numerous chlorite slickensides; patches 3-5 mm.

185. Distinct ophite; patches 4-5 mm.

186. Ophite with chlorite slickensides. Some very highly polished. The slickensides tend to run together, not exactly, but not far from at right angles to the line of intersection of the planes on which they are. Mottles about 3 mm.

187. Ophite. 2-3 mm. It seems also to be full of secondary quartz, or is it possibly primary olivine? It looks fresh but is a clear, glassy mineral with little specks all through it. On one side there is a heavy chlorite slickenside.

188. Fine grained ophite. Two pieces in this bag which do not match.

189. Fine grained trap with chlorite and calcite seams.

190. Fine grained trap with chlorite and calcite seams.

191. Fine grained trap.

192. Ophite. 1 mm. or so.

193. Fine grained ophite.

194. About the same.

195. Full of chlorite seams; probably 1-2 mm. ophite.

196. Distinctly mottled; about 2 mm. With a few chloritic specks and chlorite slickensided joints.

197. Fine grained ophite.

198. Fine grained ophite with chlorite slickensided joints.

199. Very fine grained trap; feldspar sometimes standing out in some chloritic relief with small chlorite flecks.

200. Fine grained trap with chloritic flecks. Chlorite on one face.

201. Fine grained trap. Perhaps little copper; chlorite flecks.

202. Fine grained trap and occasionally feldspars which stand out in relief, traversed by a seam of calcite. One face is coated with calcite and chlorite.

203. Fine grained, but not entirely dense, with numerous chlorite and a few calcite amygdules coated on two faces with chlorite and calcite. Note how the calcite is separated into concentric layers by red bands and agatoid appearance.

204. Rather fine grained trap with chlorite amygdules.

205. Rather fine grained trap with chloritic seams and blotches to a slight extent, but no well-defined amygdules.

206. Fine grained trap with some chlorite amygdules. This is a trap rather than an amygdaloid.

207. Fine grained trap and chloritic blotches and reddish streaks which may be altered olivine are some what more conspicuous.

208. Very fine grained, dense trap. Reddish brown with chlorite on joint faces. Not particularly striated.

209. Osceola amygdaloid. Gray, decomposed looking; full of calcite in large patches and with poikilitic effect; also epidote; and in spots; there are numerous round, smooth walled amygdules with pink prehnite.

210. Amygdaloid with red fine grained base, and various sized amygdules, smooth walled, coated with chlorite and filled with chlorite, epidote and calcite. Here as generally the epidote and chlorite are early; the calcite and prehnite are late.

Belt 56. 211. Massive fine grained trap. Few small chlorite specks.

212. Fine grained ophite and joints abundantly covered with chlorite.

213. Ophite with heavy slickensided chlorite. Mottles probably about 2 mm.

214. Ophite. Chloritic slickensided joint plane. Mottles about 2½ mm.

215. Ophite. Must have been a little copper on one of the joints, as it has bluish stains. The mottles are 3 mm.

216. Coarsely mottled ophite. 4½ mm. Soft chlorite on joints.

217. Coarse ophite. Not less than 3 mm.—probably much more.

218. Coarse ophite. 4-5 mm.

219 and 220. In here probably about the same.

221. 3-4 mm.

222. Massive ophite with chloritic joints. 4 mm.

223. Well-marked massive ophite, about 3 mm.

224. Finer ophite. 2-3 mm.

225. 2 mm. Chlorite specked in spots.

226. Full of chlorite amygdules, small and at one side greatly altered in epidote with a formation of small cavities lined with crystalline epidote and occasionally filled with calcite. Copper is disseminated in minute quantities.

Belt 55. 227. Common fine grained ophite. Some chlorite spots or amygdules.

228. Fine grained ophite with chloritic amygdules; in one case with some laumontite and a little copper. The laumontite is on seams.

229. Fine grained massive ophite.

230. Amygdaloid. Very much decayed. Full of calcite. Gray with stains of copper.

231. Fine grained. Not very amygdaloidal but full of disseminated epidote, and a hollow amygdaloid showing crystals of epidote or something else.

232. Amygdaloid with unusual chocolate red base and amygdules of epidote or a very light colored chlorite lining, and pink or white calcite centers. This very light chlorite reminds one in color of prehnite.

233. Well-marked brecciated amygdaloid. The fragments and reddish or gray amygdules with chlorite or calcite amygdules are seamed by a matrix of epidote and calcite.

234. Well-marked amygdaloid with reddish or gray ground, the

latter made up of grayish white alteration of feldspar being more conspicuous. The amygdules are calcite or light colored chlorite.

235. Amygdaloid. Hard, red and dense base and chlorite or calcite amygdules. Chlorite also occurs on seams.

Belt 54. 236. Distinct ophite. Mottles about 2-3 mm.

237. Massive ophite. Mottles 2 mm. One spot of chlorite amygdaloid. These are likely to occur anywhere in the trap.

238. Well-marked ophite. 3 mm. Slickensided chlorite face.

239. 3-4 mm. Ophite.

240. 2-3 mm. Ophite. One face has a 2 mm. calcite seam; another is heavily coated with slickensided chlorite and calcite.

241. Rather finer grained ophite. 2-3 mm. perhaps. One side is slickensided and coated with chlorite and pink calcite.

242. Fine grained massive ophite. Two pieces.

243. Probably fine grained. All cut up with chlorite seams. Massive trap.

244. Fine grained ophite. 1-2 mm. mottling. One large amygdaloid.

245. Finer grained with numerous small chlorite amygdules and few large calcite amygdules. The matrix is the usual chocolate brown.

246. Fine grained, reddish brown with few large amygdules, showing the first epidote, and about the same time also near the margin of the amygdaloid, a red calcite. This seems to be, however, a little later than the epidote in the interior. There is a clear white calcite much more vigorously effervescent, showing pressure twinning very finely, and then powdered light greenish with chlorite. The contact between the two types of carbonate is very marked.

Belt 53. 247. Two pieces. Fine grained with chlorite on the joints. Slickensided.

248. Fine grained with a reddish band of alteration passing through it, and at one side the surface slickensided and coated with calcite, chlorite and apparently iron oxide.

249. Fine grained trap with few small chlorite amygdules.

250. Dark and fine grained. Chlorite in the joints.

251. Massive, fresh, fine grained ophite. Feldspar not over 1 mm. At one end there are chloritic joints. The mottles certainly less than 1 mm.

252. Very similar. Perhaps 1 mm. mottling.

253. A good deal slickensided with chlorite and calcite. Probably somewhat mottled.

254. Massive, fine grained trap.

255. Decomposed with considerable epidote and chlorite, and fine mottling 1-2 mm. is brought out. There is also some chloritic flecking.

256. Very much altered. Apparently fine grained. Crossed by seam of epidote and one of epidote and calcite. Mass of rock seems to be full of epidote, chlorite and quartz, perhaps also some laumontite.

257. Ophite. 2-3 mm. mottling with chlorite spots and chlorite on seams.

258. Distinct ophite. 3 mm. with chlorite and epidote seams. Also a grayish green calcite and chlorite.

259. Coarse ophite, very heavily slickensided, course of the striations being at right angles to each other.

260. Fine grained ophite. Massive; somewhat reddish.

261. Ophite. 1-3 mm. Rather full of epidote and chlorite.

262. Light gray; much altered, and probably heavily charged with calcite, which also occurs as an earthy encrustation on one face. The mass of the rock appears to be white in laths with red interstices occasionally replaced by green spots.

263. Massive ophite, dark and rather fresh looking outside, and numerous chlorite slickensided faces.

264. Rather coarse and feldspathic. Faintly ophitic with a few chlorite blotches.

265. Fine grained and fresh looking.

266. Several pieces. Reddish; rather fine grained, with some small chlorite spots and fissures several mm. wide full of striated calcite and chlorite.

267. Medium grained trap, with chlorite and calcite on the faces. Mottles perhaps about 2 mm.

268. Fine grained, very red, but the feldspar laths are often conspicuous under the microscope. Apparently quite feldspathic. One seam is coated with chlorite.

269. Very similar to 268.

270. Probably somewhat mottled. 2-3 mm. Reddish with chlorite on seams.

271. Shows contact between the red, not distinctly mottled ophite and a seam of the doleritic type, with coarse feldspar 3 mm. long, coarse chlorite blotches, and apparently everything coarser.

272. Mottled 2-3 mm., probably with blotches of calcite and chlorite.

273. Apparently fine grained, massive, dark brownish trap with only occasional amygdules of chlorite.

274. Very like 273. Two pieces.

275. About similar to 274 in general ground mass, but there are well-marked banded amygdules, generally whitish at the circumference and light green at the center. There appears to be no epidote. The center may be altered prehnite. Hardness is about 4.

276. Rather fine grained reddish trap, and red specks which may be altered olivine are rather conspicuous.

277. Reddish fine grained ophite with a few chlorite amygdules.

278. Reddish, fine grained ophite with slickensided chlorite on the irregular joints.

279. Reddish trap with faint mottling, if any.

280. Massive trap, rather fine grained, with occasional small amygdules.

281. Rather fine grained with small chlorite blotches, and on the joint faces, laumontite and chlorite.

282. Rather fine grained with disseminated chlorite and laumontite and chlorite on the joints.

283. Well-marked amygdaloid. Reddish chocolate fragments. Small white amygdules and irregular filling of epidote, red calcite and white calcite.

284. Also well marked amygdaloid, with fine grained chocolate base. Disseminated chlorite and epidote, and red and white calcite in irregular fissures.

285. Same. Well developed.

Belt 52. 286. Same. Calcite shows pressure twinning very finely.

287. Fine grained trap; massive. Reddish alteration line.

288. Rather fine grained ophite. Calcite and chlorite on joint plane.

289. Massive ophite about 2 mm.

290. Dark, fine grained trap. Probably faintly mottled.

291. Ophite. 2-3 mm.

292. Ophite, with a decomposed seam, calcite and a little copper, chlorite. Mottles 3-4 mm?

293. Ophite with a heavy seam of slickensided chlorite. Mottles 3 mm.

294. Ophite, well-marked; massive. Mottles 3 mm.

295. Mottled 3-4 mm. More or less altered reddish and with heavy slickensided chlorite on seam.

296. Well-marked ophite; chlorite on seams. Mottling about 3 mm.

297. Well-marked ophite. Mottling 2-3 mm.

298. Well-marked ophite. Mottling 2-3 mm. One amygdule. One end reddish altered.

299. Massive ophite. Mottling about 2 mm. Some laumontite and calcite on seam.

300. None.

301. Rather fine grained ophite. 1-2 mm., with some chlorite and calcite on seams.

302. Fine grained ophite about 1 mm., with some blotches of chlorite; fairly distinct amygdules, also laumontite and a little copper on the joint face.

Belt 51. 303. Fine grained and a good deal crushed. Full of slickensides covered with chlorite and laumontite.

304. Probably all a piece of one pebble in conglomerate, though about 12 mm. long and fairly coarse grained rock composed of oligoclase and orthoclase and quartz. Somewhat patchy. Probably belongs to the augite syenite family. The joint is coated with calcite and there are copper stains.

305. Calumet conglomerate. Pebbles of quartz porphyry and red base, and quartz crystals several mm. across, and feldspar up to 20 mm. Orthoclase. Little stains of copper can even be seen in the quartz in the small fissures traversing the seam. The matrix consists of a red feldspar which comes next the pebble and in the little seams of the same. This is often a brighter red than the felsite matrix. The very margin of the feldspar is often bleached and it appears to have passed into a granular, secondary aggregate. Separated in most cases from the pebbles by a red zone around areas of calcite and in this copper often occurs. Besides the felsite there is at least one pebble which appears to be of the common amygdaloid, gray with calcite filling. Calcite shows pressure twinning.

306. Same as 305 with rather more matrix. One of the felsites with a darker base shows marked oligoclase phenocrysts. There is also a pebble with quartz and oligoclase phenocrysts and a rhyolitic ground. Probably some other crystals besides. In one case they seem to be replaced by epidote, which seems to line several open pores, though not apparently abundant on the rock as a whole. One green streak of carbonate of copper.

307. Seems like an ordinary amygdaloidal conglomerate with a lot of amygdaloidal fragments, with calcite filling and also epidote in the interstices.

308 A. Shows the most copper of any of this series. There is a large crystal of quartz porphyry showing distinct quartz and feldspar phenocrysts, but the ground mass seems almost to be a specular iron ore, being heavily enriched with iron oxide. There are numerous other pebbles of various kinds, and part of the same pebble which has this extra enrichment of iron oxide seems to be blanched.

309. Well-marked conglomerate. Pebbles rather smaller and the matrix composed of small fragments of various sizes. Comparatively little sign of alteration, but a little copper staining. The last matrix appears to be calcite, and there is some epidote.

Belt 50. 310. Dark ophite. Fine grained, massive, with a hackly fracture as though full of little slips.

311. Well-marked amygdaloid with amygdules bordered with red calcite and chlorite and white calcite centers.

312. Fine grained trap with little chlorite and laumontite and calcite on joints.

Belt 49. 313. Fine grained with spots of amygdaloid, with very small pores filled with red or green mineral, probably chlorite or calcite.

314. Fine grained trap. Chlorite slickensides on joints.

315. Fine grained trap. Seems to have a little tendency toward a glomeroporphyritic appearance.

316. Distinctly well-marked ophite. 1-2 mm. Slickensided chlorite on joints, in at least three different directions.

317. Marked ophite, about same grain. Very well marked slickensided chlorite on joints. Some of them also show copper carbonate.

318. Another specimen of Calumet conglomerate. Shows frequent stains of copper. Both A. & B. are Calumet conglomerate.

319. Well-marked ophite. 2-5 mm. Chlorite on joints.

320. Well-marked coarse ophite. Mottles 3-5 mm.

321. Marked coarse ophite. Mottles 6 mm.

322. Marked coarse ophite. One seam heavily coated with chlorite.

323. Coarse ophite. Mottles perhaps 5 mm. Chlorite seams.

324. Well-marked ophite. Mottles 4-5 mm. Heavy seams of slickensided chlorite.

325. Coarse ophite. Mottles about 3 mm. Chlorite seams.

326. Ophitic, growing finer. Mottles 2-3 mm. Much jointed.

327. Fine grained with slickensided chlorite seams all through.

328. Fine grained; large amount of slickensided chlorite.

329. Mottles 1-2 mm. With heavy seams of slickensided chlorite.

330. Fine grained with numerous small chlorite amygdules. Some laumontite and chlorite on seams.

331. Very fine grained, some epidote. A good deal of chlorite disseminated through the rock. Looks as though it might be brecciated trap or chlorite amygdaloid just under the main amygdaloid.

332. Is unquestionably a mistake. Sample is from a big pebble in the Calumet conglomerate, being of the augite syenite type.

333. Is amygdaloid or amygdaloidal conglomerate. Has somewhat fragmental appearance, with red and gray amygdules and calcite and epidote in the interstices. The amygdules are filled with calcite often greenish and coated with chlorite.

334. Fine grained and rather massive, but full of small chlorite amygdules. Ground mass quite brown.

335. None.

336. Brecciated amygdaloid or amygdaloidal conglomerate. There seem to be fragments of gray and red amygdules mixed in together with a good deal of epidote and calcite in the matrix. Probably this is only a brecciated amygdaloid. Cf. with bed at general horizon of the Houghton conglomerate.

337. Well-marked amygdaloid with small and fine amygdules and a bluish or reddish brown matrix and a good deal of epidote in the pores.

338. Similar brecciated amygdaloid, but the amygdaloid is more in spots.

339. May be amygdaloidal conglomerate. They appear to be irregular fragments, of different types of amygdules. There is much epidote in the interstices; as usual the epidote is next the rock and the calcite in the centers. Amygdules proper may be filled with epidote or chlorite and calcite.

Belt 49. 340. Amygdaloidal conglomerate, or amygdaloid of the same type as the previous.

341. Is similar with some rather large cavities filled in with calcite and some other minerals.

Belt 48. 342. Well-marked trap with coating of slickensided chlorite. 2-3 mm. on one face.

343. None.

344. Fine grained ophite; probably 1-2 mm.

345. Probably an ophite. Almost all surfaces old, joints with chlorite covering.

346. Marked ophite. 2-3 mm. Chlorite on joints.

347. Marked ophite. 3 mm. Heavily slickensided with chlorite on joints.

348. Marked ophite. 2-3 mm.

349. Marked ophite. 1-2 mm. Slickensided chlorite on joints.

350. "One of these, but not known which one," on bag.

The two pieces are both of ophites of about same grain, say 2 mm. One has a heavy chlorite seam on one side. The other has also chlorite seams but not quite so much and the mottling is a shade less pronounced. Probably one of these represents one of the previous missing numbers e. g. 343.

351. Ophite. Fine mottling. About 2 mm.

352. Much finer grained. 1-2 mm. Some chlorite and also a seam of calcite.

353. Fine grained with some laumontite coated seams.

354. Chloritic seams. Coarsely amygdaloidal with chlorite and calcite. Base fine grained and brown.

355. Like 354. Amygdules of calcite lined with chlorite, somewhat more numerous.

356. Also fine grained with a few chlorite amygdules. These fine grained specimens seem at times to show the feldspar a little porphyritically. In one seam a little calcite.

357. Fine grained faces covered with chlorite.

358. Well-marked amygdaloid with very small amygdules. Greenish white on a chocolate brown ground. Same type as previous amygdaloid.

Belt 47. 359. Fine grained trap. Chlorite on seams.

360. Massive trap. Mottles about 2 mm. Numerous chlorite seams on joints.

361. Ophite. 2-3 mm. Little chlorite on seams.

362. Ophite. 2 mm. Chlorite and calcite on seams.

363. Well-marked ophite. Mottles 3-4 mm. Chlorite and calcite on seams.

364. Marked ophite about 3 to 4 mm. Little chlorite on seams.

365. Marked ophite. 4 mm.

366. None.

367. Marked ophite. 4 mm. Some chlorite on joints.

368. Marked ophite. 5 mm. perhaps. Heavy chlorite seams.

369. Coarse ophite. 3 mm. Chlorite on seams. Also calcite.

370. Massive ophite. Mottles about 3 mm.

371. Massive ophite. Mottles probably 2-3 mm. Heavy chlorite seams.

372. Marked ophite. Rather fine grained. Well-marked chlorite slickensides.

373. Fine grained ophite. 1-2 mm. Very little chlorite.

374. Fine grained ophite. 1-2 mm. With occasional amygdules of chlorite.

375. Two pieces. Fine grained ophite with occasional chlorite amygdules.

376. Fine grained ophite, with some chlorite amygdules.

377. Fine grained ophite with occasional chlorite flecks.

378. Amygdaloid with large fragments of greenish amygdules, full of epidote and chlorite with quartz amygdules, cemented together by quartz. There is an open porous texture.

379. Amygdaloid with open pores. Field a light brown ground and numerous grayish green amygdules.

380. Amygdaloid with a gray and red amygdaloid mixed. The amygdules are filled with calcite, but are lined with epidote or gray-green chlorite. The whole rock seems highly decomposed.

Belt 46. 381. Fine grained massive trap with red line of decomposed and heavy slickensided chlorite seams.

382. Very fresh looking, fine grained rock, but with much calcite on seams.

383. Fine ophite. Possibly 2-3 mm. With chlorite and calcite on one face.

384. Ophite. About 2 mm. mottling, with little chlorite.

385. Ophite with chlorite and calcite on one face.

386. Fine grained with occasional chlorite amygdules, with rather feldspathic looks.

387. Fine grained trap with few small chlorite amygdules.

388. Fine grained trap with small chlorite and calcite amygdules.

389. Amygdaloid. Yellow-green, full of epidote and quartz, with very good showing for copper. There is also calcite.

390. Amygdaloid. Fine grained, brecciated, red amygdaloid with pink amygdules. Is cemented together largely by epidote. There is also quartz. Cf. the Montreal lode.

391. Fine grained trap with few amygdules and copper stains.

The following samples are, I believe, from the Calumet cross-cut:

A. Massive trap with heavy seams of chlorite.

B. Massive fine grained trap; chlorite and epidote.

C. Fine grained ophite, 1-2 mm. Some chlorite.

D. Is well-marked brecciated amygdaloid with red and gray amygdaloidal fragments, and in interstices epidote and calcite and perhaps some other mineral.

E. Augite syenite pebble with some conglomerate.

F. Heavy ophite. Mottles 2-3 mm. Considerable chlorite.

A bag marked "Calumet Conglomerate" contains samples of conglomerate mainly with other fine grained felsitic pebbles. The ground mass a lighter red and copper a good deal represented by red oxide and green carbonate.

There are too many sections to place on the figure 37. Slight discrepancies between the shafts may not be due to inaccuracies of records but to slight changes along the strike.

A section at 3200 feet in the Centennial that I took with some care is worth re cording for the fact that it shows that the third belt under the Calumet conglomerate which it will be noticed is irregular in different sections is not an amygdaloid top at all but a slip. It is a mile north of the main section. The record follows:

51.	Calumet conglomerate Ss. 16544-16546	(27)
52.	Amygdaloid 27-54 Ss. 16547-16548	(16.8)
	Trap 54-62 Ss. 16547-16551	(100.9)
53.	Ophite	
	Amygdaloid 262-? Ss. 16552-16554	
54.		(75.3)
	Trap -816 Ss. 16554-16563	(242.7)
	Slip with dip 35° at 390	
55.	Ophite	
	Amygdaloid 816-840 Ss. 16564-16566	(10.6)
	Trap 840-898	(87.8)
56.	Amygdaloid. Supposed to be Osceola 16	(10)

The Tamarack 13th level cross-cut gave:

51. Calumet conglomerate
52. A. 35 (21.8) and T. 145 (90.4)
53. A. 50 (31.2) and T. 220 (137.2)
54. A. 20 (12.5) and T. 95 (59.2)
55. A. 40 (25) and T. 145 (90.4) with copper
56. Osceola amygdaloid 750 feet from shaft

Below the Osceola the old 4th level Calumet, and 30th level Tamarack sections give substantially agreeing records, allowing for slips, down to and below the Kearsarge conglomerate and close to the Kearsarge amygdaloid. The section might have been extended by Calumet and Hecla drilling but in the figure it is completed by the Old Colony records about two miles northeast which were at the time in a little better shape. However, for the record of the character of the beds in drill holes consult Calumet and Hecla drill holes D. C. and A.

Holes A. D. and C are nearly in line with the long cross-cut of the Calumet and Hecla shown in the plate and continue its section. They are in turn to be continued by drilling on the St. Louis property;[1] Section 19, T. 56, R. 32,

[1]Since completed. See Appendix.

making a section S. 56° 33' W. from Kearsarge shaft No. 20. They are also continued by the drilling around Kearsarge shaft No. 21.

Calumet and Hecla drill hole D. Drilled northwesterly from C, about 400 feet from it, practically at right angles to the beds, dip 50°. About 650 feet above the Wolverine sandstone, and about the horizon of the Kearsarge conglomerate.

1. Overburden (32)
2. Base of ophite (32-53) (21+)
   At d D. 32 2 mm. mottles. Over 42 feet thick,
   This is probably the thick ophite just below the Kearsarge.
   Cf. the 98-foot belt 4577-4701 at Red Jacket and the No. 46 belt in the cross-cut 2579-2632 at Franklin Jr.

70. 3. Amygdaloid d D. (53-63) 10 feet, to
   Ophite d D. -86 23 (33)
   From 78-81 pseudamygdaloid, i. e., spotted by alteration so as to look like amygdaloid. Cf. 14.2+44.2 of a cross-cut, nearby.

71. 4. Amygdaloid? and ophite 86-144 (58)
   Possibly a continuation of Belt 3.
   At 96, 115, and 140 feet we have the
   mottling 2, 2-3, and ½ mm. across.
   Cf. 197 and 203 in cross-cut for 3 and 4 together make up 91 feet against 98.5 of the cross-cut.

72. 5. Red amygdaloid with calcite seams and
   Amygdules (d D. 144-153) 9 feet, top of
   Ophite d D. -158 4 feet (14)
   1 mm. mottling at 155 feet?

6. Amygdaloid (d D. 157-161) 4, top of
   Melaphyre (d D. 161-164) 3 (7)
   Base below the base of the Kearsarge conglomerate, about (200) to (300) feet.

73. 7. Amygdaloid (d D. 164-166) 2 feet, top of
   Melaphyre (d D. -187) 21 (23)
   The trap is more or less amygdaloidal and somewhat ophitic; 5, 6 and 7 may belong together. The three amygdaloids are probably grouped in the cross-section.

74. 8. Amygdaloid (d D. 187-194) 7 feet, top to
   Ophite d D. -271′ 6″. 74 (85)
   At 207, 212, 226, 248, 257, 271 feet the
   mottles are 2, 2½, 3, 3-4, 4, 1-2 mm.
   At 235 to 236 there is a green, fine grained amygdaloid bomb.

77. 9. Amygdaloid (d D. 271′ 6″-277 to 9) 5 feet, top to
   Melaphyre d D. -320 43 (48)
   From 289 to 304 feet, semidoleritic and pseudoamygdaloid. Then more compact, massive and faintly ophitic.
   Base below base of the Kearsarge conglomerate (356) to (456) ft.

78. 10. Amygdaloid (d D. 320-328) 8 or less feet, top to
   Melaphyre (d D. -264) 36 feet + (44)+
   This melaphyre is faintly amygdaloid for a good part of the way, fine grained and not apparently ophitic. If it is the same belt as No. 2 of C, and it can not well be any lower one, it must be the upper part of the same flow, which is probably over 70 feet thick. Thus

D extends from 320 feet or so to 650 feet above the Wolverine sandstone.

Calumet and Hecla drill hole C. Put down about 400 feet northwesterly from A and at an angle of 50°, so as practically to overlap it.

1. Overburden of till (566)

78. 2. Bottom part of ophite (d C. 566-84) (27+)
This is coarse, rather feldspathic, pyritic (secondary?) and grows denser. Total (say 74)
Base above the Wolverine sandstone (288 ft. +)
Base below the Kearsarge conglomerate (356 to 456+say 74) (430) to (530)

79. 3. Amygdaloid (epidote, chlorite, laumontite and calcite) (84-87)
top 3 feet of
Melaphyre (89′ 6″) 2 (5)

4. Amygdaloid (4 d C. 89′ 6″-91) top 2 feet of
Melaphyre (which is coarsely amygdaloid to 95 ft.) to 102′ 11″ (13)
The lower contact has red trap above, yellow-green below.

80. 5. Amygdaloid, yellow-green (d C. 102′6″-109) 7 feet, and then
Coarse chloritic amygdaloid (d C. 109-113) 4 feet, top to
Feldspathic melaphyre (d C. 113-135) 2 (33)
From 84 to 226 feet may be one throughout coarsely amygdaloidal flow in overlapping gushes, 142 feet thick.

81. 6. Amygdaloid, becoming coarse (d C. 135-142 to 157?) 7 feet, top of
Feldspathic ophite, Kearsarge hanging, -226½ 84½ (91)
At 188 to 198 feet, laumontite, at 206 3 to 5 mm. mottles.
Base (top of Kearsarge amygdaloid) above the Wolverine (145)+

82. 7. Kearsarge amygdaloid (d C. 226½ to 235) 8½ feet, top to
Ophite, Kearsarge foot (d C. 235 to 281½) 46½ (55+)
The amygdaloid is dense, with white, red bordered amygdules.
The ophite is a plagiophyre like Belt 2 of A, quite dense to begin with but with ophitic mottles about 3 mm. across at the (281′ 6″) end, about the same as A at 108 feet, which would make the thickness 55+ (198-108).
This is about the right thickness, as we see upon comparison with A. Hole C then gives a record from 90 to 315′ 6″ above the Wolverine sandstone.

Calumet and Hecla drill hole A, put down practically at right angles to the dip, in a nearly continuous section with E and D on Section 13, T. 56 N., R. 33 W. No correction for true thickness from apparent thickness. The first numbers correspond to those on the section. (Fig. 37).

1. Overburden (54)
2. Begins in the immediate foot of the Kearsarge lode or amygdaloid, the rock still faintly amygdaloid, a red porphyritic melaphyre, with crystals, turned greenish, of labradorite which at 67 feet seem coarser and up to 15 mm. long, the augite becoming ophitic at 75 feet.
Rough observations of the size of the ophite mottlings are:
at 86, 107, 108, 121, 134, 156, 164, 171, 179 feet

3 mm., 4–5?, 3, 4, 4–5, 3, 2, 1–2, 1, respectively; the base is a very dense fine grained, blue trap to 198 feet

A plagiophyric ophite, the Kearsarge foot thickness (about 150 feet, allowing for amygdaloid) (144)+

83. 3. Wolverine sandstone. Absent as in Section 23? (0)
and part of the section cut out?

84. (to obtain distance below it subtract about 200 feet).

85. 4. Epidotic, brecciated amygdaloid (d A. 198-203) for 5 feet, top of-
Ophite (d A. 203-273) 70 (75)
mottling at 208, 223, 258 feet
1 to 2, 2 to 3, 3 mm. respectively
at 254 prism shaped augite patches; at 239 to 242, 249 and 254 to 258 veins.

86. 5. Amygdaloid (laumontite, quartzose, veined) (270-279) for 9 ft. the top to-
Ophite, feldspathic and doleritic above, (to 361) 84 (93)
Ophitic mottling at 320, 326-348 feet
3, 2-3 mm. respectively

87. 6. Amygdaloid (d A. 361-367) for 6 feet, top to-
Melaphyre (d A. -370) 3 " (9)

7. Amygdaloid (d A. 370-377 for 7 feet more, then-
Melaphyre -381 for 4 feet (11)
It is fine grained, red, and more or less amygdaloid from 379 down.

8. Amygdaloid (d A. 381-394) for 13 feet, then-
Melaphyre (d A. -397) for 3 feet 16

9. Amygdaloid (d A. 397-399) for 2 feet, then-
Melaphyre (d A. -401) for 2 feet 4

It is impossible from a drill hole record in the case of such belts as 6 to 9 to determine whether they are not fewer belts, or one rather small flow more or less amygdaloidal throughout (40) feet thick. Cf. B 120-163, and Hole 1 near Shaft 21 from 70-92 feet.

10. Sediment on top of scoriaceous amygdaloid. Thickness can not be separated from it. Below the Wolverine sandstone horizon 203 ft.

87. 11. Scoriaceous amygdaloid (d A. 401-405) for 5 feet, on top of-
Feldspathic ophite (d A. -553) 148 feet (153)

This melaphyre remains sparsely amygdaloid, with an occasional speck of copper, some way below 411, and becomes coarse (in one spot 10 mm. feldspar and 7 mm. augite and chlorite amygdules) and doleritic with very little traces of ophitic texture:
at 515 and 540 feet
mottles perhaps 5 and 2 mm. respectively

The base is fine grained green, the contact with the next underlying flow uncertain.

88. 12. Amygdaloid (d A. 553-555) for 2 feet? top to-
Melaphyre (d A. -656) 101 feet (103)

In this melaphyre the feldspar and brown specks (I presume of altered olivine) are conspicuous, and even the magnetite and chlorite, but the ophite mottling is but faintly visible. The bottom 4 feet are first a dark grey, then a red and white amygdaloid and would probably be counted with the underlying amygdaloid in mining.

Belts 11 and 12 seem closely associated and may be one flow with inclusions. Cf. B 233 with A 401. No thoroughly satisfactory

correlation of these holes can be made owing probably to the disturbances near B.

89. 13. Amygdaloid (d A. 656-661) for 5 feet, top of-
Ophite (d A. -752.6) 91.6+ say 145 (160?)
It is coarsely amygdaloid down to 678. The mottling is plainer than from 401 to 556:

at	678,	692,	706,	732,	738,	752
the mottles are about	2,	3,	4,	5,	6,	4–5 mm.

whence I think we are safe in inferring 50 feet or so more of the trap to the next amygdaloid, making the total thickness about 160 ft.

Calumet and Hecla drill hole 1. Near shaft 21. This was put down in the exploratory drift about at right angles to the lodes, i. e., about 50°.

85. 1. Ophite with inclusion spots? of finer grain d 1. 0-70 (70+20?)

at	0,	18,	40,	57,	68 feet we have
mottles	2,	3,	1–2,	2–3,	1–2 mm.

It is probably feldspathic.

86. 2. Amygdaloid (red with white amygdules (d 1. 70-84) 14 feet, top to
Melaphyre (d 1. 84-92) 8 (22)
Cf. Hole A, Belts 6 to 9.

3. Sediment mixed with

4. Amygdaloid, marked (d 1. 92-97) 5 feet top to
87? Feldspathic ophite (d 1. ?-232) 135 (140)
At 104 and 113 feet there is red sediment, perhaps filling a seam. At 111 and 155 it is pseudamygdaloid, and at 140 doleritic. In general the ophite mottling is vague but at

130,	204,	213 feet it seems to be
3–4,	3,	5 mm.

5. Amygdaloid (d 1. 232-240) 8 top of
Melaphyre (green epidote) (12)

6. Green sandstone and fluccan (244-256) (12)

7. Amygdaloid, coarse feldspathic (d 1. 256-271) 15, top of
Feldspathic melaphyre (d 1. -330+) 59 (74+)
This melaphyre is doleritic, and epidotic, coarse and feldspathic, with conspicuous brown spots of altered olivine. At 288 is a fine spot inclusion or bomb.

Belt 7 resembles A 12, and Belt 4 may represent A. 11; and Belt 3, A 10; and belt 2, A 6, 7, 8, and 9; Belt 1, A 5. Belts 5 and 6 would then be either part of the amygdaloidal top of 7, or faulted in, or deposited in a hollow of flow 7 before 4 came over.

This would make the top of d 1 come about 102 feet below the horizon of the Wolverine sandstone. According to the mine plan it is about 125 feet below the slide that cuts out the Wolverine sandstone, and in the cross-cut that leads to it there is:

Trap 109 feet.
Amygdaloid (pseudamygdaloid on which a drift was run follow- a fissure dipping 60° about at right angles to the dip) 14 ft. and-

84. Trap 16 (93)
Amygdaloid (on mine plan) 17 and
85. Trap to beginning of hole 12 (20)

Calumet and Hecla drill hole 2. In exploration shaft 21. Put down under ground as shown in plat; nearly at right angles to the dip.

1. Melaphyre, base of bed (d 2. 1-9) (9+)
2. Scoriaceous conglomerate (d 2. 9-12+) (3+?)
3. Melaphyre? (d 2. 12-15) (3?)

87. 4. Amygdaloid with red sediment, (d 2. 15-20) 5 feet, top of Feldspathic melaphyre (d 2? to 167) (152?)

Red sediment is frequent along here, but is probably either washed or faulted into seams, so at 40 and 48 feet. The bed is but faintly ophitic. At 56 it is faintly ophitic, 2 mm. At 70 is a coarse amygdaloid streak, probably not a contact, but probably at 81. At 95 it appears finer grained; at 100 2 mm. mottling; at 118, a clay slip, ophitic mottling, 3 mm. At 125 it is coarser, but veined and so altered that the ophitic character is faint. At 149 the mottles appear to be 4 to 5 mm., at 159 2 mm. and 167 a contact.

This belt is so much disturbed that one can not depend upon its thickness, but it corresponds to Belt 4 of Hole 1.

5. Epidotic conglomerate and sandstone, (d 2. 167-175?)

Indurated fine grained grey and green, scoriaceous conglomerate at base.

6. Scoriaceous amygdaloid (d 2. 175-185) 10 top of Melaphyre, feldspathic ophite (d 2. -282) 97 (107)

The record of the samples is again not clear. Red sediment occurs at 193; an inclusion at 258; at 210-215 there is an amygdaloid streak, possibly a contact (cf. 288 feet in Hole 1) at 223 an epidote streak; at 230 possibly a fine grained contact but no amygdaloid. This may be an inclusion bed or flows more than one closely associated.

7. Sediment, red, with belt below. 0
8. Amygdaloid (d 2. 282-294) 12 feet, top of Melaphyre (d 2. -315) 6 (33+)

This is epidotic from 294 to 299 feet and shows fine grained inclusions.

The beginning of this hole appears to be not far from (200) feet below the level of the Wolverine sandstone in A but from its position in the mine it is not over 50 feet below the slide representing the Wolverine sandstone. Yet the scoriaceous amygdaloidal belt appears to be the second belt below the Wolverine, at any rate is separated by considerable trap. Thus from 70 to 160 feet extra is taken up in the slide fault, the balance perhaps in the slip which passes through the drill hole at 118 feet:

B. near shaft 21

Ophite coarsest at 97 feet	75 to 118		(43)+
Amygdaloid, top to beds below	118	123	(5)
Amygdaloidal melaphyre	123	163	(40)
Amygdaloid, tops to beds below	163	167	(4)
Melaphyre (faintly ophitic about	218ft).	233	(66)
Scoriaceous amygdaloid		236	(3)
Melaphyre (feldspathic)		305	(69)
Amygdaloid (four feet)			
Melaphyre (feldspathic, rarely doleritic and 434 faintly ophitic)		456	(154)

Sandstone, dark red	463	(4)
Melaphyre (feldspathic and doleritic)	560+	(97)

3 of Shaft 21. All one belt, (82) the Kearsarge foot trap a plagiophyric ophite, very fine grained near the bottom of the hole,

mottles at	20,	40,	58,	67,	100,	113,	167 feet are
about	1,	2,	3–4,	3,	5,	4,	3–4 mm.

across and the end is obviously getting finer and near the top, the Kearsarge amygdaloid lode which was sought. Subsequent exploration proved this to be the case.

§10. OLD COLONY-TORCH LAKE (FIGS. 38 AND 39.[1])

The lower part of the Calumet section is represented by work done on the Old Colony and Mayflower which is incorporated in Figure 37.[2] Of these workings more or less has been examined by members of the Survey at various stages. The main record of the met Section (Fig. 37). Belts 109, 110, and 111 correspond to Torch Lake, Hole No. 2, probably Belts 11, 12 and 13. The Mayflower is also proving this same territory. Some notes by P. S. Smith and W. V. Savicki of an early stage in the work follow and are illustrated by Fig. 39.

The tunnel has already cut three conglomerates.

Facts, etc., furnished by Mr. Chas. Chynoweth of the Centennial mine.

Specimens of conglomerates. Locations shown in notes of W. V. Savicki. Conglomerate from tunnel of the Old Colony Mining Company. A true conglomerate rather dark reddish. Pebbles of amygdaloid trap, a dark trap with narrow decomposed crystals of feldspar, sandstone, considerable calcite in veins and seams. The pebbles are not very well rounded being subangular. The specimen shows a fracture on breaking which cuts across the pebbles.

Conglomerate No. 5 from Leinenen's pit so-called. Rock appears to be a breccia rather than a conglomerate. There is considerable epidote. The fragments are very angular with a smashed up matrix of comminuted fragments cemented with the epidote. There are many open cavities almost like druses. Specimen No. 1.

Conglomerate from pit No. 3, that is the so-called north shaft. This conglomerate looks very much like the specimen from the tunnel, much more so than like the specimen from No. 5.

Capt. Rapson is in charge of the driving of the tunnel being driven by the Old Colony Company.

Sandstone. This is the eastern sandstone not seen in contact.

52,	(34.3)	Conglomerate, Specimen No. 2.
70,	(46.2)	Amygdaloid and amygdaloid trap. With bunches of calcite No. 3.

[1] Figs. 38 and 39 are in envelope.

[2] It has been impossible to incorporate current work in this report which is of date 1909. See appendix. Figures 38 and 39, however, include facts gathered by A. H. Meuche, not referred to in the text. But it should be carefully noted that even in Figure 39, the lode labelled "Mayflower Lode" is not that which has been more recently so called. This latter seems to lie a short distance above the St. Louis conglomerate, much in the position of the Isle Royale-Arcadian Lode. Compare the tunnel record at 986 feet.

200,	(132′)	Brecciated amygdaloid, so-called conglomerate by the miners. Specimen No. 4.
265,	(175′)	Sandy like brecciated amygdaloidal trap. Specimen No. 5.
365,	(241)	Same as No. 5. This specimen is No. 5a.
495,	(328)	Small vein of amygdaloid much broken up with some slips and gouges. Too broken to take specimen. Strike of vein N. 3° E. (mag.) The dip is pretty steep, about 65°.
500,	(370)	Specimen 5 b, the same as No. 5.
710,	(468)	Specimen 5c, same as No. 5, only coarser.
830,	(548)	Broken up and altered material followed by an amygdaloidal trap with greenish chloritic balls and particles.
840,	(554)	Dark amygd. trap. No. 6 with epidote? Altered to chlorite with calcite bunches here and there.
865,	(571)	Same as No. 6, but shows feldspar needles No. 6a.
925,	(611)	Clay slips about 3 feet wide, striking N. 12° W.
954,	(630)	Fluccan seam about 6 inches wide with much decomposed material, part of seam is made up of epidote material much chloritized. This seam has caused some caving necessitating lagging.
986,	(651)	Top of No. 6 which shows some copper stains.
987,	(652)	Amygdaloid No. 7 large round amygdules.
1050,	(695)	Dark greenish, somewhat decomposed trap with greenish blotches resembling the luster mottled trap. No. 8.
1100,	(726)	Same as No. 8. Between these two there is a band of amygdaloid much the same as No. 7 but with ill-defined walls.
1155,	(762)	Moderately fine grained amygdaloidal trap much the same as No. 7. No. 9.
1590,	(1049)	No. 10. Amygdaloidal trap with epidote in the amygdules.
1603,	(1058)	Top of amygdaloid separated by a thin fluccan seam from the overlying conglomerate. No. 11. The gouge is about 2″ wide.
1605,	(1060)	Conglomerate No. 11.
1652,	(1090)	Hanging of conglomerate followed by trap. The contact is much decomposed forming a band easily traced by the eye.
1665,	(1099)	No. 12 of the trap overlying the conglomerates. This is an m. c. g. amygd. trap passing gradually into an amygdaloid.
1730,	(1142)	The amygdaloid has the amygdules filled with quartz in large measure. No. 13.
1845,	(1151′)	The hanging of the amygdaloid is at 1745. At 1730 they have turned off drifts N. and S. on the amygdaloid and are now sinking a winze on the hanging. The winze is now down 65 feet, and short drifts have been turned off.
1760,	(1161′)	A coarse even grained trap breaking with great smooth faces very massive. No. 14.
		Between 1800 and 1900 there are many intersecting seams of calcite.
2040,	(1346′)	Same as No. 14. No. 15.
2100,	(1386′)	Seam of broken up and decomposed material.
2210,	(1459′)	A clay slip conducting water in very small amount, but still the most seen in the mine.
2300,	(1518′)	Two intersecting clay slips.
2510,	(1656′)	Breast in same kind of trap.

Length of tunnel as measured 1656: Length of tunnel as measured by the Company at the first of the month 1625:

Specimens 1 to 15 above are described as follows: (of them there are preserved in the Survey collection Ss. 19736 (1), 19737 (5), 19738 (8), 19739 (11), and 1974(14)).

T. 56 N., R. 32 W.

No. 1. A conglomerate with fully formed pebbles. The cement being a greenish, epidotic mixture of small comminuted fragments of various rocks cemented together with this epidote. Texture is very open and full of cavities. The pebbles noticed in hand specimen are a reddish, much iron stained amygdaloid with round bullet like amygdules. A dark trap very fine grained. Minerals indistinguishable. (19736)

No. 2. A conglomerate with fully formed pebbles, general reddish cast. The rock as a whole breaks across the pebbles and shows no lamination or sandstone layers. Veins of calcite intersect the hand specimen frequently. Amygdaloid, sandstone, trap and felsitic pebbles are observed.

No. 3. Is a dark amygdaloid. Amygdules filled with greenish epidote and calcite. In hand specimen are several copper stains in the amygdules. Rock breaks very angular. Color dark to black. Bunches of calcite of frequent occurrence on joint planes.

No. 4. So-called "conglomerate," which in reality is a much brecciated amygdaloid showing slickensiding on faces. General color black with a good deal of laumontite.

No. 4a. In general the same as No. 4 but with much more chloritic material. joint planes.

No. 5. A sandstone and conglomerate band with rather small pebbles. The pebbles seem to be of a dark more or less siliceous rock whose exact nature cannot be determined in hand specimen. (19737)

No. 5a. Is also a conglomerate but with the small pebbles much less well formed than No. 5. The various pebbles noted are a dark trap, a reddish felsitic rock and the whole is cemented together in large part with a calcite matrix. Specimen is preserved in collection.

No. 5b. Shows essentially the same feature observed in No. 5 and No. 5a. The rock breaks across the pebbles.

No. 5c. A much more amygdaloidal breccia than preceding specimens. The specimen shows numerous slickenside planes and the pebbles are very poorly formed. The largest fragment is of a reddish trap with much elongated amygdules filled with calcite and a little epidote.

No. 6. A moderately fine grained trap verging in part into an amygdaloid with the cavities filled with a greenish chloritic material, probably an alteration product from epidote. The amygdules show elongation in the plane of bedding. Some calcite seams intersect the rock.

No. 6a. Same as No. 6, but in general with coarser grain.

No. 7. A fine grained amygdaloid. The amygdules showing a general paragenesis of calcite and epidote. The epidote has for the most part been changed into a green chloritic mineral. The rock is in general very fine grained, the individual minerals being indistinguishable to the naked eye.

No. 7. Same as preceding but with amygdaloid cavities much smaller and less altered showing passage before noted from epidote to chlorite.

No. 8. A much decomposed poikilitic rock with decomposed feldspar (?) in great abundance. This form merges into No. 7. It is traversed by many small calcite seams which causes the rock to break into angular fragments. (Sp. 19738)

No. 9. A reddish amygdaloid, very abundant small amygdules. The amygdules filled with greenish chloritic mineral. Rock breaks with an angular fracture. Amygdules show only slight elongation in any direction. Some slickensiding.

No. 10. A much less decomposed amygdaloid than preceding. Amygdules filled with greenish epidote, sometimes in beautiful little crystals. Amygdules also filled with radiating calcite. Roek generally fine grained. Texture reddish color.

No. 11. Another so-called conglomerate band by the miners but which appears in the hand specimen as a much brecciated rock. The pebbles if any, are poorly formed and show extreme angularity. The matrix is of epidotic material and the rock in general has an appearance like No. 1, except that the pebbles are not nearly so well formed. The pebbles observed are of a brownish red trap with reddish amygdules of laumontite and dark homogeneous trap, a reddish felsitic looking rock and some ordinary brown trap.

This specimen is preserved in the collection. (19739)

No. 12. Is a moderately coarse grained diabasic trap of very uniform texture occurring in very massive bands.

No. 13. Is a slightly brown, dove colored rock with large amygdules sparingly scattered through the rock. Amygdules filled with calcite, epidote and some chloritic alteration material. The rock is intersected by many calcite veins.

No. 14. A dark homogeneous trap with a moderately coarse grained texture breaking with conchoidal fracture showing considerable quartz, augite, calcite and a greenish chlorite. This rock in the mine occurs in very large massive walls. This specimen is preserved in the collection. (19740)

No. 15. Same as No. 14, but showing some slickensiding and appears a little coarse grained.

Compare the early explorations on the property described in Volume VI, Part II, page 80.

A more systematic record than that of the Old Colony can, however, be made from the work of the Torch Lake Mining Company which follows. The interesting points in this section are the flattened dips toward the lower part, over a boss of felsite or quartz (porphyry), the presence of a coarse quartz porphyry intrusive, shown in the railroad track but missed in the section, and the very pumiceous amygdaloids and felsites of the lower part. The flattened dip toward the contact is confirmed by the shaft at 33° all in amygdaloid at the Old Colony and the results of a section made by the Calumet and Hecla at right angles to their strike (S. 56° 33′ E) from their Kearsarge shaft No. 20 across the Old St. Louis property.

Torch Lake Mining Company. Thacher Loring, President. W. W. Stockly, Engineer and Superintendent. The explorations of this company are a series of drill holes and test pits of great value in determining the geological cross-section at Calumet below the Kearsarge lode. This crosses the property (which consists of two square miles, Sections 35 and 36, T. 56 N., R. 33 W.) at the extreme northwest corner. From this point to Hole 9 the country has not been explored, as comparatively little of the lodes would be found on the property of the company. They would be found on the properties of the Laurium and La Salle adjacent.

At right angles to the strike the distance of Hole 9 from the hanging of the Kearsarge lode is 1865 feet. Assuming this dip to be 42°[1] we have (1865 x .67) (1250) feet below the top of the Kearsarge lode for the position of Hole 9. The succession

[1]This is the dip derived from the Tecumseh holes and used in putting down Tecumseh Hole 2 which stayed in the lode.

of beds is, however, very fairly known from the Franklin Junior, Tecumseh, Caldwell and Arcadian work. Following the latter, we have:

	Kearsarge lode and foot	(161	1089
Arc.			(1250)
64.	Wolverine sandstone often cut out, "Conglomerate 9".		
	The Arcadian section is as follows:		
65.	Ophite	(82)	
66.	Melaphyre	(51)	
67.	Scoriaceous conglomerate	(5)	
68.	Melaphyre (inclusion bed)	(217)	
69.	Scoriaceous conglomerate	(1)	
70.	Melaphyre	(32)	
71.	Ophite	(95)	
72.	Ophite	(143)	(625)
73.	Fault zone or sediment	(25)	
74.	Feldspathic ophite, mottling not well marked, with a little copper	(190)	
	Below base of Wolverine sandstone		(840)
75.	Feldspathic ophite	(122)	(962)
76.	Sandstone 8½ cupriferous	(4)	(966)
	Cf. Old Colony sandstone, 980 feet below the Wolverine.		
77.	Feldspathic ophite, doleritic	(78)	
78.	Feldspathic ophite, doleritic Arc. 21 to 95	(54)	
	From base of Wolverine sandstone		(1100)
79.	Ophite?	(28)	
80.	Feldspathic ophite, doleritic, cupriferous	(120)	(1248)
	Possibly flow No. 2 of Hole 9, 113-268		
81.	Brecciated amygdaloid and feldspathic ophite	(83)	
82.	" " " melaphyre	(15)	
83.	Scoriaceous " " doleritic ophite	(78)	(1424+)
84.	" " " feldspathic melaphyre	(116)	(1540+)
85.	Melaphyre, not ophitic cf. d 9. 392-535	(110)	

The occurrence of copper in Holes 9, 8 and 1 seems to be matched also at about this horizon in the Old Colony, Mayflower and parallel sections.

Specimens 20563 to 20598 are taken from this section and there are microscopic descriptions of 20575, 20578, 20582, 20584, 20587, the Minong-trap-like Bed 59.

Torch Lake drill hole 9. 1380 paces N. 1600 paces W. Section 35, T. 56 N., R. 33 W. Vertical; reduction factor cos 42°=.743.

1. Feldspathic ophite? d 9. 26-113=87+ (65+)

   The reddish specks of (altered olivine) Iddingsite are plain. Augite mottling is not plain. Some hard seams (at 100 one that looks like a dike) occur, and pink prehnite (at 75′ 3″ and at 113). This pink prehnite is like that which occurs in the neighborhood of the Isle Royale lode (Vol. I, Pt. III, p. 15, but cf. also p. 103) and the traps exposed on the street railway cuts in East Houghton.

2. Feldspathic ophite? 155 (115)

   Amygdaloid d 9. 113-146

   Clasolitic and brecciated with chlorite; perhaps an amygdaloid conglomerate; looks conglomeritic; with calcite and epidote.

Trap d 9. 146-268

The altered olivine (iddingsite) is conspicuous; augite mottling is relatively obscure; from 225 to 253 it appears faintly; at 225 2 mm; at 233 3 mm.

There are amygdaloid spots to 161 feet. About 183 there are laumontite seams. At 190 is radiated thomsonite or prehnite; at 183 and 207 are seams at 10° and 5° to the core respectively, probably nearly vertical joints. Toward the base the rock is darker chloritic and the seams at 28°, 34° and 41° to the horizontal are more nearly parallel to the bedding.

3. Feldspathic melaphyre 124 (92)

Amygdaloid d 9. 268-301

Quartzose, calcitic, laumontitic, with a good deal of clasolitic matter and perhaps a contact at 272; at 292 epidote and datolite; from 301 on, trappy with irregular clasolitic seam with curious bedding banding.

Trap d 9. 301-392

From 301-335 are bands of feldspathic seams at angles from about 26° to the core, and cross-fractures at 45°.

4. Feldspathic melaphyre 143 (106)

Amygdaloid d 9. 392-407

Red and white, well-marked with a little clasolitic matter.

Trap d 9. 407-535.
also d 8. 20-54

There are occasional amygdaloid spots, and especially from 433 down chloritic spots and seams; at 451 there is a little *copper*, and again at 511 and 530 in seams respectively at 15° and 26° to the core. These are probably in the columnar joints, this being the hanging of a lode.

Top of lode below the top of the Kearsarge lode, (1647) feet, ... below Conglomerate No. 9 1250-161+397 (1486)

5.] Melaphyre. Lode and foot.

Amygdaloid d 9. 535-9.545
d 8. 57-65

Chloritic, red.

A seam of prehnite pink with *copper* at 545. This bed matches quite well Arc. 86 i. e., the marked red amygdaloid with some copper at d 21. 663-667 which is (1650) feet below the base of the Wolverine sandstone No. 9.

The brown specks of altered olivine in Arc. 86 remind one, however, of the top of No. 9, but that is perhaps a matter of the kind of alteration. The general character of very feldspathic beds, faintly if at all, ophitic, is, however, quite similar.

Torch Lake drill hole 8. 1460 N. 1200 W. Sec. 35, T. 56 N., R. 33 W. The top of this matches No. 9 at 503 feet well enough.

A uniform reduction factor is taken of cos. 41°=.755 though the dips may be somewhat less and the hole more nearly perpendicular to the beds at the bottom.

(4.) Trap d 8. 20-54

Feldspathic with black chloritic flecks matching d 9. at 503.

5. Feldspathic melaphyre, copper bearing amygdaloid and foot 121 (91)

d 9. 535-545+
d 8. 57-65 to 85?

From 57-60 the amygdaloid contains pink prehnite; from 62-65 it is not only pink but has green epidote, and spots of prehnitic pink amygdaloid occur to 65. also from 79-85.

Trap d 8. 65 or 85-178

Spots of pink prehnitic amygdules occur throughout the trap. Near 128 it seems to pass a big slide dipping 41°, probably about parallel to the dip of the beds, the rock being much shattered. If Bed 5 were the same as No. 4 something would have been cut out here. At 153 is quite a little *copper* in a seam at about 41° and there are other seams parallel to this and a faint coarse mottling. (1577)

6. Feldspathic ophite 4 mm. 85 (64)

Amygdaloid d 8. 178-190

Coarse with epidote and calcite.

Trap d 8. 190-251 to 263

Faintly mottled 190-200, coarser to 226 3 mm. mottles. There are seams at 5° and at 45° to core, then below at 230 to 235 marked seams at 20° to core. This may be a columnar jointing running nearly north. The grain grows finer from 4 mm. at 226 to 1 to 2 mm. at 247. The base of this flow is red with the feldspars standing out well and a few white amygdules but mainly green. This is like the base of the flows near the Isle Royale lode. The contact is not well marked but from grain and all appears to be down somewhat below 251. This is the first distinct ophite.

7. Feldspathic melaphyre 40 (30) (1641)

Amygdaloid d 8. 251 to 263-270

Spots of amygdaloid not well marked.

Trap d 8. 270-303

Seamed at 5° to 10° and 45° to core.

7 is very probably closely allied with No. 6,—only a preliminary gush.

8. Melaphyre 12 (9) (1672)

Amygdaloid d 8. 303-307

Trap d 8. 307-315

(1681)

9. Melaphyre 8 (6)

Amygdaloid d 8. 315-317

Trap d 8. 317-323

Base, hanging of lode below Wolverine (1687)

10. Melaphyre with a copper bearing amygdaloid 81 (61)

Amygdaloid d 8. 323-337

There is a little *copper* in small seams of 3-5 mm. which run down as a seam from the amygdaloid. In the trap below there is pink prehnite.

Trap d 8. 337-404

Cf. d 1. -15

Feldspathic and epidotic; growing distinctly finer, chloritic and jointed toward the well-marked base. The relation of this to 8 and 9 is uncertain. They may be considered one broad amygdaloidal top.

The top of 1 is feldspathic with a few chlorite amygdules, Sp. 20563 =d 1. 14

(1748)

11. Feldspathic melaphyre, glomeroporphyritic 62 (47)

Amygdaloid d 8. 404-413
d 1. 15 or 18?-29

With epidote and calcite.

Trap d 8. 413-467
d 1. 18?-67

This trap down to 443 remains irregularly streaked and occasionally amygdaloid with pink bordered amygdules, altered, fine grained and glomeroporphyritic, that is, with clots of small feldspar laths. From 448-462 it is massive, coarser and feldspathic, then the glomeroporphyritic appearance becomes more marked toward the base. At the top of Hole 1 there is a similar difficulty in making out exact flows; from 29 to 37 it is feldspathic trap, then a red amygdaloid, then epidote and chlorite amygdules, then pink, white and green amygdules.

Base hanging of lode below Wolverine (1795)

12. Feldspathic melaphyre, glomeroporphyritic, with *copper* 45 (34)

Amygdaloid d 8. 467-473
d 1. 67-77?

Copper at d 8. 471 feet, the first noted in this hole.

Trap d 8. 473-512
d 1. 77-91

The amygdaloid is not well marked, glomeroporphyritic, the contact seems to dip 31° and breaks parallel to it; dip 31° to 41° at the top; grows finer from 499 down. In hole 1.67-77 has pink and white amygdules but the first copper is noted at d 1. 113 in a trap, on chlorite, epidote and calcite, the marked cupriferous amygdaloid which is also glomeroporphyritic being at d 1. 106-110 feet. This is probably amygdaloid 13.

1829.

13. Feldspathic melaphyre, glomeroporphyritic 75 (57)

Amygdaloid d 8. 512-517
d 1. 106-110

Glomeroporphyritic Sp. 20582 is at d 8. 513 a glomeroporphyrite.

Sp. 20582 at d 8. 513. Is a typical glomeroporphyritic amygdaloid with bunches of plagioclase feldspar 1-2 mm. across on a rusty ground with smaller feldspars, chert. quartz, etc.

The amygdules are full of crystalline yellow epidote, calcite, sometimes chalcedony, and chlorite. The calcite is in large areas and latest formed. The epidote has various shades of yellow.

The calcite has negative fluid cavities with bubbles.

I think I recognize some thoroughly altered serpentinous olivine, but it is difficult to distinguish certainly from augite.

The feldspar is much decomposed. Under the microscope the olivine is in large altered phenocrysts altered to serpentine. The augite is .012 to .020 mm. in size. It is about 2-½ feet from the margin. The feldspar is distinctly in two generations. The larger are about .40 x .22 mm. Extinction angles indicate $Ab_5\ An_3$. The ground mass is composed of small microlites .07 to .12 mm. x .02 mm. The extinction angles are very low but it is largely decomposed. The feldspar is replaced not only by epidote but also by some brown material of high refraction and low birefraction. The larger feldspars are grouped and

bunched together as they represent an early stage of consolidation but are not sharply defined rhyocrystals. The amygdules are of yellow epidote and chlorite and also calcite altered in formation. There is also a mineral with a refraction much greater than chlorite with birefraction between feldspar and augite, extinction $\pm$ 0,—2V, small always and in fibres transverse to the elongation. Its properties are something like brucite. There is also a mineral with low refraction and birefraction and optically negative which is probably laumontite.

Trap	d 8.	517-587
	d 1.	110-178

At d 8. 546 feet there is a seam of datolite and *copper* at about 45° to core, and at d 8. 580 ft. there is copper in the trap.

At d 1. 113 there is also quite a little copper in a feldspathic trappy rock, then below a brown feldspathic trap from d 1. 156 down, growing finer and more plainly glomeroporphyritic.

	Base, hanging of lode, below Wolverine				(1886)
				By Hole 1	(1880)
14.	Copper bearing glomeroporphyrite		53		(40)
	Amygdaloid, copper bearing	d 8.	587-593		
		d 1.	178		
	Amygdaloidal trap	d 8.	593-618		
			-ab.205		

There is perhaps a second flow.

This remains somewhat glomeroporphyritic and the amygdules are well charged with copper, a very promising lode.

In No. 1 at 178 feet there is also well-marked copper. The amygdaloid is at first gray chloritic, becoming reddish with epidote and calcite, passing gradually into the trap with amygdaloidal flow lines.

Trap	d 8.	618-640
	d 1.	205?-227?

Coarse, feldspathic and massive, then glomeroporphyritic; similar in 1; but the contact is not easily located.

	Base of Hole 8 below Wolverine sandstone 9			(1926)
(15.)	Amygdaloid	d 8.	640-648	
		d 1.	227?	
		d 1.	178	

Red, white and green amygdules, with a little copper.

Trap	d 8.	648-676

Feldspathic and glomeroporphyritic.

Hole 1 does not match this very well from d 1. 227 down since d 1. 244 is doleritic and d 1. 258 ophitic and d 1. 227. shows no copper; yet a correlation of d 8. 640-648 with d 1. 178 runs into difficulties too, as d 1. 106-110 is the first amygdaloid above, at a considerably greater distance than d 8. 587. It seems on the whole likely that in 8 are some beds of the cupriferous glomeroporphyritic series that are cut out in 1 perhaps by seams noted at 200 feet. This cupriferous series of relatively feldspathic glomeroporphyritic beds are well matched by the series of beds Arcadian 80-90.

Torch Lake drill hole 1. 1275 N. 1070 W. Sec. 35, T. 51 N., R. 33 W. Vertical.

Comparing 1 and 2 the correlated dip is about 36° and near the top at 200 feet are flow lines indicating a similar dip tan-1 15 to (11 or 12) (36° to 38°½). The dip from Hole 8 to Hole 1 would be also tan-1 409 ÷ 563 ± according to the strike about 36°

Flow lines are noted at	15:12 at 83 feet
	15:11 at 200 feet
seams	15:11 at 322
amygdaloid lines at	15:9 at 478
	60:43

This would indicate a dip of 35°½ and a reduction factor of .813 which makes the thickness of the belts agree with those supposed to correspond in Hole 8.

The copper at the top of 1 and the bottom of 8 may be compared with the Old Colony No. 2 and No. 1 lodes.

Hole 1 begins in a series of amygdaloids and amygdaloidal traps in which the exact number and dividing lines of the different flows it is not easy to make out in disintegrated beds near the surface. The largest number possible would be about as follows:

Feldspathic trap d 1. 0-7? 7 (6)

(11′) Epidotic amygdaloid d 1. 7?-18? 11 (9)

(11″) Feldspathic glomeroporphyritic at base
d 1. 18?-37+? (15)

(11‴) Feldspathic melaphyre with coarse amygdules, pink, white and two shades of green (epidote and chlorite), glomeroporphyritic at base
d 1. 37+to d 1. 67 (24)

(12′) Another flow (20)
Amygdaloid d 1. 67-77
Coarse pink and white.
At 77 seams at 20° to core.
Amygdaloidal trap 77-91, epidotic, streaked by bands of varying texture, dipping about 38°.

(12″) Glomeroporphyrite (12)
Amygdaloid d 1. 91-100
Trap d 1. 100-106
Judging from Hole 8 12′ and 12″ are one flow.

(13) Glomeroporphyrite (57½)
Cupriferous amygdaloid lode d 1. 106-113, with epidote, calcite and copper even in foot trap at 113
Trap d 1. 113-178
Feldspathic and growing finer and more distinctly glomeroporphyritic from 151 down. This seems quite clearly to be 13 of Hole 8. 512-587.
Base below Wolverine (1886)

(14) Feldspathic melaphyre (49) (40)
Amygdaloid d 1. 178-179+
Gray, calcitic with considerable copper, becoming reddish, with epidote and calcite amygdules.
Trap d 1. 179-227?
Feldspathic, slightly amygdaloid to d 1. 205, with amygdaloid

flow lines at 36° dip, and at 200 feet seams, perhaps due to faulting. (1926)

15. Feldspathic ophite, 10 mm. 233 (189)

Amygdaloid d 1. 227-230

Coarse with epidote and chlorite amygdules.

Trap d 1. 230-470

d 2. 0-146

At 244 feet almost doleritic. The augite mottles

at	258,	289,	320,	334,	369,	415 feet
are	2-3,	5,	7,	10,	8-10,	5-7 mm. respectively

Then below it grows finer and between 458 and 470 glomeroporphyritic.

(2115)

At d 2.14 the mottles are 10 mm., and remain about the same to d 2. 65. The iddingsite is conspicuous at d 2. 65-98. From d 2. 98 the grain is finer and the mottling fainter. The correlation of Hole 2 at 146 with Hole 1 at 470 is very good.

No. 15 is so heavy a belt that we may expect to find it quite persistent. Now, we find Arc. No. 92 a heavy belt 211 feet thick or so Arc. 4. 1-32, the foot of which was about 2270 below the Wolverine.

Also in Isle Royale Consolidated Hole 4, 244-449 Bed 3 is also 184 feet thick, has faint mottles, 7 mm. at 314-354, has conspicuous altered olivine and matches excellently, and is the hanging of the Isle Royale lode.

I am inclined to think that all these correlate though it implies that the Arcadian lode is not the Isle Royale but one 180 feet below.

The uncertainty and difficulty may be due to faulting at some part of the formation. So far as the distances are concerned changes in the dip well within the limits of possible error could account for them as well as variation in the thickness of beds. It is curious to note that comparing Arc. 80-92 with Torch Lake 2-15 we come out with just about the same number of beds, though no attention was paid to that feature. The iddingsite, altered olivine, is noteworthy especially from 347 to 415. At 322 is a seaming at 36° and 54° dips, also about 369 chloritic seams at about 15°-20° with the hole, and at 430 feet again.

Sp. 20564 is from drill 1 at 458 feet.

Base below base of Wolverine (2115)

(16) Feldspathic ophite 4 mm.

Amygdaloid d 1. 470-478

d 2. 146-156

Epidotic and laumontitic with amygdaloid lines dipping about 31°, also seams at 14° to the core.

Trap d 1. 478-518

d 2. 156-207

Massive, faintly mottled 4-5 mm. at d 1. 510 feet; faint 3 mm. mottles at d 1. 185

The seams are at 15°½ to the core, also dipping 22° and 53°.

Torch Lake drill hole 2. 1092 paces N., 980 W. Sec. 35, T. 56, R. 33. Vertical. The dip of the beds here is between 33° and 27°½. We take the latter figure which means a reduction factor of .875.

(15.) Feldspathic ophite d 2. 0-146

Note how in this feldspathic bed the iddingsite is prominent.

16. Feldspathic ophite 3 mm. 61 (53)

Amygdaloid d 2. 146-156

With pink, green and white amygdules. This *may* be the Isle Royale lode.

Trap d 2. 156-207

Massive, feldspathic, 3 mm. mottles near 185 ft. Seams make 12°½ with the core.

(2168)

17. Feldspathic ophite 3 mm. 83 (72.5)

Amygdaloid d 2. 207-217

Red, brecciated

Trap d 2. 217-290

Feldspathic, faintly ophitic 3 mm. near 256, growing finer toward the bottom. Considerably seamed.

Sp. 20578 is from Torch Lake, Hole 2 at 230 feet. It seems to have had a great deal of olivine, now reddened and changed to "iddingsite." Numerous cavities are filled with fibrous coatings of chlorite. The feldspar extinctions indicate an andesite. The hand specimens show a peculiar rice-like flecking that looks like an ophitic texture in which the augite patches were somewhat prismatic.

(2241)

18. Feldspathic melaphyre 92 (81)

Amygdaloid d 2. 290-300

Red to 292; chloritic amygdaloidal trap -296, then red to 299, then at 300 yellow and green and white.

Trap d 2. 300-382

d 3. -296

Massive, feldspathic, white flecked, seams dipping 50° and 52°, and between 340 and 347 the core follows closely a vertical fissure that splits the drill core. The face of this fissure is slickensided at an angle of about 45° to the core, indicating probably a displacement along the fissure in a direction nearly parallel to the dip. At 376 the dip seems to be (tan -1 15:9) 31° on a seam of red calcite. No. 3 is faintly and coarsely mottled perhaps.

Base below Wolverine (2322)

19. Feldspathic melaphyre 74 (65)

Amygdaloid d 2. 382-393

d 3. 29′ 6″-35

Epidote, chlorite and calcite. Dip 36°½ in No. 3, light green and white and epidotic with a speck of copper.

Trap d 2. 393-456

d 3. 35-96

Massive, feldspathic. The Iddingsite is not conspicuous as above. Joints are at 36° to core (nearly at right angles to dip?) in No. 3 also

feldspathic with laumontitic seams at 34° to core; at d 3. 73 feet nearly parallel, at d 3. 67 radiated prehnite.

	Base below Wolverine sandstone		(2387)
20.	Feldspathic ophite	68	(59)

Amygdaloid d 2. 456-465
d 3. 96-99

Contact uncertain; much broken about d 2. 460-463; red; seamed at dip of 15°, then the amygdaloid is greenish.

Trap d 2. 465-524
d 3. 99-134?-167

Curiously mottled, probably decomposed or weathered, ophite mottled, as below 509 the trap and the mottles grow finer. Cf. d 3. 117-130, which has also peculiar mottles, and 130 is at the same time mottled and has chloritic amygdules, being very exceptional, until we get to Hole 7.

	Base below base of Wolverine	(2445)

(21.) Amygdaloid d 2. 524-530
d 3. 164?-174?

Coarse, epidotic, with calcite and chlorite. Seams dip 39° to 45°; flow lines less, 39° to 34°. At d 3. 134 are flow bands dipping 22° and beneath it is much finer grained.

Trap d 2. 530-557
d 3. 134-167

At this horizon at d 2 520-540 are seams 15:120 and 15:15 and amygdaloid flow lines well developed. The same is true in d 3. 134-156 (15:6 flow; 15:33 seams; 15:15 seam), but the contacts are not plain and the mottling is abnormal and the bed probably disturbed.

Sp. 20578 at d 2. 230 is very thoroughly altered but still shows the diabasic structure of irregular radiating plagioclase laths characteristic of ophites. The interstices between the laths are very red. There is probably also primary iron oxides, some chlorite in an amygdaloid cavity, some calcite disseminated perhaps, also some cherty silica.

The feldspar is rather low angled and appears to be andesite.

Torch Lake drill hole 3. 770 paces N. 775 W. Sec. 35, T. 56 N., R. 33 W. Vertical. The dip of the beds is about 26° ½=tan-1 7:15. The factor for reduction to true thickness is cos. 26° ½=.895

(18.)	Feldspathic melaphyre or ophite	d 2.	290-382		
		d 3.	0-29½		
(19.)	Feldspathic melaphyre	d 2.	382-456	74	(65)
		d 3.	29½-96	66½	(59½)

(20.) Feldspathic ophite. Peculiarly mottled with flow bands.

d 2. 456-524	68		(59)
d 3. 96-or 167	38 or 71	54	

There is no marked contact at 134 but between that and 136 is a finer grained band and at 134 the flow bands show. In the coarser seam near

156 feet the iddingsite shows. The seams are at 45° and 24° with the core. From d 3. 165-167 appears finer and seamed.

Sp. 20566 comes at d 3. 130 — 2445
21. Feldspathic ophite 4 mm? (78?) (70)

2515

Amygdaloid d 2. 525-530+
d 3. 167?-174

Slightly amygdaloidal, gray, with coarse and sparse amygdules. Seams dip 26° ½ to 18° ½ and are laumontitic. The contact is certainly above d 3. 182.

Trap d 2. 530-557
d 3. 174-245

With scattered amygdules, massive at 212, faintly mottled at 223 to 224, 4 mm., at 228 seams at 31°; at 234 feet 18°½. It may be that this bed is partly cut out at the seams.

22. Feldspathic melaphyre 38½ (34)
Amygdaloid d 3. 245-259
Trap d 3. 259-283½
Feldspathic; seams dip 37°

(2550)
23. Feldspathic melaphyre 19½ (17)
Amygdaloid d 3. 283½-292

Contact well-marked, dip lines 37° and 25°. A red and white amygdaloid to 287, then epidotic green and white the next five feet.

Trap d 3. 292-303

Feldspathic (2567)
24. Amygdaloidal melaphyre 9 (8)
Amygdaloid d 3. 303-310
With epidote, chlorite, calcite.
Trap d 3. 310-312
25. Amygdaloidal melaphyre 6 (5)
Amygdaloid d 3. 312-317
Trap d 3. 317-318

d 4. -34 (2580)
26. Amygdaloidal melaphyre 10 (9)
Amygdaloid d 3. 318-321 4.34
Trap d 3. 321-324
Amygdaloid d 3. 324-328

d 4. 43 (2589)

This base shows a well-marked contact with a well-marked dip about 25°.

27. Feldspathic melaphyre 22 (20)
30 (27)
Amygdaloid d 3. 328-341
d 4. 43-45

The contact is shattered and marked and dips about 25°, it is full of epidote and calcite to 333. Toward the base the flow lines dip

33°¾ and there are pink seams at 26°½ to the core, probably columnar jointing.

Trap d 3. 341-350
d 4. 45-73

At d 4. 62 there is a seam at 27° to core and also nearly parallel. Possibly there is about 8 feet repetition here as Holes 3 and 4 do not exactly agree, but the sum of flows 27 and 28 agree.

(2609)

28. Melaphyre 20 (18)

Amygdaloid d 3. 350-358
d 4. 73-75 10 (9)

Green
Amygdaloid trap d 3. 358-361
Trap d 3. 361-370
d 4. 75-80

Well-marked basal contact dipping 31°. This checks well in both holes. (2627)

29. Melaphyre 19 to 22 (17 to 20)

Amygdaloid d 3. 370-373
d 4. 80-90

A spot of amygdaloid also at d 3. 378. Cf. 3.90

Trap d 3. 373-389 or 392
d 4. 90-111

Fine grained, brecciated and slickensided foot; in No. 4 also jointed and fine grained.

(2646)

30. Porphyritic melaphyre 19 (17)

Amygdaloid d 3. 392-400 24 (22)
d 4. 111-131

Much altered and epidotic to 395

Trap d 3. 400-411
d 4. 131-135?

This trap has in No. 3 3 mm. phenocrysts of feldspar (labradorite), slightly glomeroporphyritic, but more separate than usual. At 401 is a seam (nearly parallel to the dip?) dipping 36°. This flow and the one below are probably all one.

(2663)

Sp. 20567 comes at d 3. 404

31. Porphyritic melaphyre 46 41
36 (32) (41)

Amygdaloid d 3. 411-412
Cf. d 4. 135-137?

Finer, more amygdaloidal, only a spot?

Trap d 3. 412-457
d 4. 137-171

Feldspathic, massive, with good cores.

In No. 4 the clasolitic contact seems to be at d 4. 138 and dips 41°. From d 4. 135-137 is finer, more amygdaloid, with a red ground,—a foot amygdaloid. At d 4. 138 the porphyritic series in which the plagioclase is so conspicuous seems to begin corresponding in that

respect to d 3. 457. In 4 there is also a contact at d 4. 148 with gray amygdaloid to 152 feet and flow lines dipping 25°. Then labradorite and iddingsite conspicuous in the massive trap below, down to d 4. 161, very much like d 3. 434.

(2704)

32. Porphyritic melaphyre 10 (9)
10

Amygdaloid d 3. 457-461

Amygdules not abundant, but markedly porphyritic.

d 4. 171-178

Marked amygdaloid with red ground on which are epidote amygdules and light plagioclase.

d 3. 461-467

d 4. 178-181

Probably just a gush of the flow below.

(2713)

33. Porphyritic melaphyre 14 (12)

Amygdaloid d 3. 467-472 20 18

Marked red, porphyritic, with epidote and calcite.

d 4. 181-186

Slightly amygdaloid contact uncertain.

Trap d 3. 472-481

Porphyritic with Iddingsite and plagioclase on red ground. Dip lines 31° to 41°

d 4. 186-201

Massive, feldspathic, fine seams indicating bedding?, dip about 30°.

(2725)

34. Porphyritic melaphyre 10 (9)
14 13

Amygdaloid d 3. 481-486

Marked gray, flow lines dip from 22° to 31°

d 4. 201-

Porphyritic with 3 mm. plagioclase.

Trap d 3. 487-491

d 4. -215

Plagioclase phenocrysts up to 7 mm. long.

35. Porphyritic melaphyre 11 (10)

Amygdaloid d 3. 491-5

d 4. 215-217 9 8

Epidotic.

Trap d 3. 495-502

Feldspathic plagioclase phenocrysts up to 5 mm. long, with bedding seams dipping 31° and columnar joints at 28°½ to core.

d 4. 217-224

While the exact correlation of individual flows so small as these may be uncertain, on the whole this series of markedly porphyritic beds are quite characteristic and the records in the two holes agree to 10 feet. Cf. in the Central mine section the beds about 2975 ft. below the Wolverine sandstone 97-115. On the other hand we can not identify these

very well further south. Cf., however, beds above the Isle Royale lode on Isle Royale and Douglass streets in Houghton

(36.) Amygdaloid d 3. 502-505-9 (2744)
Amygdaloid, but continues chloritic and porphyritic to the end.
d 4. 224-225
Contact uncertain with epidote and calcite.
Trap 3
d 4. 225-239
Marked iddingsite at 228 feet.

Torch Lake drill hole 4. 690 paces N., 615 W. Sec. 35, T. 56 N., R. 33 W. Vertical. The dip to d. 3 is about 26°½ to d. 5 about 24°½. A reduction factor of .9 seems proper.

Specimens 20568, 9, 205670, 1 are from
d 4. 418, 396, 399, 469 feet respectively

Down to d 4. 224 the record overlaps that of three and is given above as follows:

(25)	Amygdaloidal melaphyre d 4?-34			
	Base below Wolverine			(2580)
(26)	Amygdaloidal melaphyre	Am. d 4.	34-39	
		T.	-43	
(27)	Feldspathic melaphyre	Am. d 4.	43-45	
		T.	-73	
(28)	Melaphyre	Am. d 4.	73-75	
		T.	-80	
	Checks well with d 3. 370	base below Wolverine		(2627)
(29)	Melaphyre	Am. d 4.	80-90	
		T.	-111	
	Base is top of porphyritic series d 3. 392.			
	Below Wolverine			(2646)
(30)	Porphyritic melaphyre	d 4.	111-135?	
(31)	" "	Am. d 4.	135?-137?	
		T.	-171	
(32)	" "	Am. d 4.	171-178	
		T.	-181	
(33)	" "	Am. d 4.	181-186	
		T.	-201	
(34)	" "	Am. d 4.	201-215	
(35)	" "	Am. d 4.	215-217	
		T.	-224	
	Base below Wolverine (by No. 4 7 feet more) by No. 3			(2744)

36. Porphyritic melaphyre 15 (13.5)
Amygdaloid d 4. 224-5
Epidote and calcite, contact uncertain.
Trap d 4. 228-239

Iddingsite, marked at 228 (2758)

37. Porphyritic melaphyre 36 (32)
Amygdaloid d 4. 239-247
Epidotic, altered, cold gray for the first foot, then red porphyritic.

Amygdaloidal trap d 4. 247-275

Feldspar and iddingsite prominent; with amygdaloidal and other spots; at 263-267 the feldspar conspicuous, then to 269 amygdaloidal, epidotic, very likely a streak or inclusion; then porphyritic; a seam at 13° to the core. Contacts are uncertain. All these beds may be one inclusion bed.

(2790)

38. Porphyritic melaphyre 64 (57.6)

Amygdaloidal trap d 4. 280-339

At 285 the feldspar phenocrysts are 7 mm. x 1 mm;

Amygdaloidal d 4. 285-7; also d 4. 288-290; from d 4. 293-299 it is coarsely feldspathic; from d 4. 299-302 amygdaloidal, then below a marked massive glomeroporphyritic trap growing red and more distinctly porphyritic at base.

The contact at the base is the first really marked one below 202 feet. There is a little sediment and a well-defined dip of from 25° to 26°½.

39. A very little sediment. Dip 25° to 26°½.

Base below base of Wolverine (2848)

40. Porphyritic melaphyre 18 (16)

Amygdaloid d 4. 339-348

Trap d 4. 348-357

Trap grows red and porphyritic at d 4. 355, near the base joints are at about 35°½.

(2864)

41. Porphyritic melaphyre 26 (23)

Amygdaloid d 4. 357-370

Glomeroporphyritic.

Trap d 4. 370-383

Feldspar 5 x 2 mm. There is perhaps a contact near 375 feet. The contact dips 28° (?), but there is also a seam at 25°.

(2887)

42. Amygdaloidal porphyritic melaphyre 68 (61)

d 4. 383-451

d 5. -53

The texture is glomeroporphyritic with pink and green feldspars on a maroon base, and frequent amygdaloid spots, epidote amygdaloid inclusions at d 4. 400-4.420-422, and d 4. 443. Toward the bottom contact the porphyritic texture is plainer, as is almost always true.

Sp. 20569 is at 396 feet.
" 20570 " " 399 "
" 20568 " " 418 "

(2948)

The top of No. 5 appears to be this same flow. Beginning in an epidotic amygdaloid at d 5. 23′ 6″ to 24, then glomeroporphyritic, finer and redder to 25, gray to 28, red and epidotic to 29, gray to 32, trappy to 39, gray epidotic to 40, red porphyritic to 41, gray to 42, and glomeroporphyritic to 53.

43. Porphyritic melaphyre 56 (50)

Amygdaloid d 4. 451-457
d 5. 53-71?
Trap d 4. 457-507? or 484?
d 5. 71?-82

Glomeroporphyritic, with amygdaloid spots at 484 and 494. This is where the contact was drawn judging by hole 5 in that hole. Peculiar yellow (siderite?) amygdules; feldspar 3 mm. long; at 473 a line of flow?, at 35° to core; at d 4. 497 cavities with rhombs probably siderite.

Sp. 20571 is at d 4. 469 feet.

In these glomeroporphyritic beds it is difficult to place the base of the amygdaloids or to separate them.

(2998)

44. Porphyritic melaphyre 25 (22)

Amygdaloid d 4. 507?-or 484-510
d 5. 82-117

Contacts not certain. At 100 it is a little spotted and at 114-117 is an epidotic altered seam.

Trap d 4. 510-532
d 5. 117-139

The bottom contact is very well marked and has sediment associated. The dip is 22° to 28°, or another place 25°. The dip also shows well in Hole 5, from d 5. 142 down with dips of flow bands 29°½, at d 5. 118 the coarse feldspar is much like that at d 4. 543.

(3020)

45. Porphyritic melaphyre 26 (23)

Amygdaloid d 4. 532-542
d 5. 139-142
Trap d 4. 542-558
d 5. 142-165

Coarse glomeroporphyritic to 552, then toward base darker and fine grained. Lowest of the porphyritic beds. d 5. 118-123 and d 5. 159 are both like d 4. 544-552.

(3043)

46. Melaphyre 11 10

Amygdaloid d 4. 558-563
d 5. 165-169
Trap d 4. 563-569
d 5. 169-188?

At d 5. 178 a 2 mm. ophite?

(3053)

47. Melaphyre 13 12

Amygdaloid d 4. 569-572?
d 5. 188-

Regular type red; a well-marked contact but not much of the amygdaloid.

Amygdaloidal trap d 4. 572?-582
d 5. -192

(3065)

48. Melaphyre 11 10

Amygdaloid d 4. 582-585

d 5. 192-197

Called amygdaloid spots but apparently quite persistent.

Trap d 4. 585-593

d 5. 197-202

(3075)

49. Melaphyre 40 (36)

Amygdaloid d 4. 593-597

d 5. 202-207

Pink and white

Trap d 4. 597-633 or 635

d 5. -239 or 245

Massive, dark, at d 4. 619 are signs of a 25° dip; at 625-628 a vertical seam. From 630 down it gets red porphyritic. Cf. d 5. 178 a 2 mm. ophite? also d 5. 237 dark but glomeroporphyritic.

(3111)

50. Amygdaloidal melaphyre 23 (21)

Amygdaloid d 4. 633-642

d 5. 239-or 245-?

There is a contact at d 4. 633 and again at 635 just a ropy coil of lava? The amygdaloid is red porphyritic. This corresponds to the well-marked basal amygdaloid in d 5. 239-245. While the exact correlation of these gushes is difficult, the general correlation of glomeroporphyritic red basal looking beds at the top of 5 and in 4 above 561 feet is plain.

Amygdaloidal trap d 4. 642-656

d 5. 245-261?

d 5. 245 with some copper is the best marked amygdaloid and contact. Underneath it passes into a gray and quartzose amygdaloid.

(3232)

51. Melaphyre 4

Amygdaloid d 4. 656-658

d 4. -261

Trap d 4. 658-660

d 4. 261-272

(3236)

52. Melaphyre 31 (28)

Amygdaloid d 4. 660-665

d 5. 272

Yellowish, green (epidotic) and white.

Amygdaloidal trap and amygdaloid -691.

Amygdaloid 670-675 and 678 to 680.

(3164)

53. Melaphyre

Amygdaloid d 4. 691-

Dip 28°?

d 5. 290

This contact has also a marked dip in Hole 5.

Torch Lake drill hole 5. 550 paces N. 350 paces W. Sec. 35, T. 56 N., R. 33 W. Vertical. The dip from the average of 17 observations on joints, flow lines, and contacts is (tan-1 126:255) 26°⅓, by correlation of beds it is 24°¾, but if the strike is more east of north than the main range and not at right angles to Stockly's cross-section, the dip by correlation of the beds would be steeper and there is reason to believe this is the case. It would imply a swing of the strike 20°. Cf. the exposures of Sp. 20575 a Minong-trap-like bed (as recognized by myself years ago in the Douglass Houghton Ravine and by myself and Stockly independently in the cores, and confirmed by microscopic comparison) at d 5. 525. The reduction factor need not be changed.

(42.) Amygdaloidal porphyritic melaphyre d 4. 383-451
d 5. -53
Base below base of Wolverine (2948)

(43.) Porphyritic melaphyre d 4. 451-484?, d 5. 53-82 (26)
Dips of bands 26°½ and 22°. Gray coarse feldspar.

(44.) Porphyritic melaphyre d 4. 484-532, d 5. 82-139 (51)
Epidotic amygdaloid, porphyritic trap, at 100 spotted pink, d 5. 114-117 epidote seam. At 118 coarse feldspar.

(45.) Porphyritic melaphyre d 4. 532-558, d 5. 139-165 (23)+
Flow bands 22° to 39°. Quartz epidote amygdaloid at d 5. 153-7.

(46.) Melaphyre d 4. 558-569, d 5. 165-188 (21)-
Red amygdaloid and trap not markedly porphyritic, possibly ophitic.

(47.) Amygdaloidal melaphyre d 4. 569-582, d 5. 188-192 (4)-
Red to gray, only a gush.

(48.) Melaphyre d 4. 582-593, d 5. 192-202 (9)
From d 5. 192-197 amygdaloid spots; a clasolitic seam at 45° at base.

(49.) Glomeroporphyritic melaphyre d 4. 593-635, d 5. 202-245 (39)-
Feldspar 5 x 2 mm.

(50.) Amygdaloidal melaphyre d 4. 635-656, d 5. 245-261? (14)+
With copper; dips 15° to 25°; amygdaloid gray and quartzose at base.

(51.) Amygdaloidal melaphyre d 4. 656-660, d 5. 261-292 (10)

(52.) " " d 4. 660-691, d 5. 272-290 (16)

(3161)

Or by the record in No. 4 3164 feet (3164)

The beds just above all tend to be feldspathic, amygdaloidal, porphyritic, with red porphyritic bases and not augitic.

53. Melaphyre 9 (8)
Amygdaloid d 4. 691-695+
d 5. 290-294
Red amygdaloid contact dips 25°
Trap d 5. 290-299

(3172)

54. Melaphyre 22 (20)
Amygdaloid d 5. 299-304
Yellowish gray.
Trap 304-321
Seams at 18°½ dip at 309 feet.

(3192)

55. Melaphyre 21 (19)
Amygdaloid d 5. 321-329

Contact dips 22°
Amygdaloidal trap d 5. 329-341

			3211
56.	Melaphyre	33	(30)

Amygdaloid d 5. 341-9
Gray and mixed.
Trap d 5. 349-374
d 5. 341-351 slightly glomeroporphyritic, then a 2-foot seam altered epidotic; d 5. 357-358 and amygdaloid spot.

			(3241)
57.	Amygdaloidal melaphyre	13	(12)

Amygdaloid d 5. 374-379
Amygdaloidal trap d 5. 379-387
Varicolored, coarsely amygdaloidal.

			3253
58.	Porphyritic melaphyre		
	Amygdaloid d 5. 387-390	28.	(25)

Gray, quartzose and epidotic.
Trap d 5. 390-5.415
d 6. 13
d 7. 20
Dark, fine grained, slightly porphyritic; at d 5. 402 a joint at 14° from core (columnar) just above the contact which seems to dip 33°?

			(3278)
59.	Augite porphyrite, Minong trap type	154	(137)
		165	
		135	(3415)
		ave 151	

Amygdaloid d 5. 415-418
d 6. 13-16 or 25
d 7. 20-23?
Trap d 5.418-569
d 6.16 -178
d 7.23 -155

This is a well-marked horizon and characteristically fine grained, recognized by W. W. Stockly and myself independently, and two or three times over as different from the usual beds and like the Minong trap on Isle Royale. We have a number of specimens:

Ss. 20572 at d 5. 485
3 580
4 516
5 525
6 531
7 535

I do not think there can be any question as to the correlation between the holes.

Sp. 20575 at d 5. 525 feet is an augite porphyrite, U. M. There is little or no sign of olivine, a great abundance of labradorite and a scanty amount of augite which acts nevertheless as a sort of cement between the feldspars and tends to be ophitic.

Labradorite extinctions are Ab_1 An_1 0°-30°; 18°-11°; 12°-18° and in a Karlsbad twin 35-28°, also 4°-5° with 19°-18° in a Karlsbad twin, the former individual much more birefractive.

We have also such extinctions as the following:

14° to 14° (greater birefraction) with 43° to 26° (less birefraction); 18° to 22° with 43° to 27°; 11° to 12° with 7°.

Sections nearly parallel to M (010) show low colors; extinction against P (100) 16°. It must be near Ab_4 An_3. There is primary as well as secondary iron oxide. The former is younger than the feldspar, at any rate in part, and older than the augite.

The augite grains run about .12 mm. from .05 to 2 mm. A tendency to prismatic form is quite noticeable, but the amount of augite is smaller and, while it is interstitial, it varies in form from the xenomorphic to idiomorphic. A fragment of coarser crystallization is enclosed. In this coarser piece the augite is more xenomorphic. The texture is doleritic, since one interstice is filled with chalcedony spherules. There is also replacement by zeolite with very low refraction and birefringence which may be laumontite.

I think it can also be recognized on the street railway line and the course of the Douglass Houghton Creek.

In all places the well developed amygdaloid is thin (in No. 5 from 415-418, red and brecciated; in 7 from 420 to 423 gray with copper, calcite, quartz and epidote.) Then to d 5. 430 it is fine grained, from d 5. 430-468 is slightly coarser but after all always peculiarly fine grained. As the base is approached the columnar joints appear at 22° to the core, 11°½ and 31° along about d 5. 500. From d 5. 501-527 is all fine grained trap with no appreciable change in grain. At d 5. 528 feet are minute specks of copper. Was it an extra hot flow or an intrusion? At d 5. 536-539 there is a somewhat amygdaloidal belt, and at 549 the feldspar is much plainer, approaching a porphyritic appearance. At d 5. 562 feet is brown clasolitic matter in the red porphyritic marginal trap, evidently a stringer of that underlying.

In No. 6 the amygdaloid is brecciated a foot to d 6. 36, then fine grained and mixed amygdaloid to d 6. 39, then brecciated and red to 43, then a fine grained trap with minute porphyritic feldspars to 46, then brecciated a foot; and brecciated again at d 6. 51-55, and at d 6. 57-60, at d 6. 62 there is a curious banding dipping 50°, then all the rest the way a fine grained trap; the columnar jointing growing more prominent; at first irregular; from d 6. 115 down plainer, at 29° and 25°½.

In No. 7 the contact is at 17°; then there is a brecciated amygdaloid with quartz and epidote and yellow amygdules; faint mottling? and small amygdules to d 7. 51, 31 feet below the top; cf. d 5. 430+ and 6.39. Below that it, too, is massive. At d 7. 67 to 121 the dip by banding appeared to be 26°½ and at d 7. 88 was a suggestion of 1-2 mm. mottles. From d 7. 121 on down the grain was aphanitic.

60. Sediment d 5. 569-570
d 6. 178-179 ±
d 7. 155

Very thin, only a foot or less, dips 18° to 22° in Hole 5
15°-18°½ " " 6
21° or so " " 7

Base below base of Wolverine (3416) ft.

This is the very first bed that can by any possibility be correlated with Conglomerate 8. The greater distance is no objection but the beds associated are very different.

61. Amygdaloid

d 5. 570-580?
d 6. 179-180
d 7. 155-156

In Hole 6 clasolitic with yellow amygdules.
7 also a thin amygdaloid with marked contact.

d 5. 580?-605
d 6. 180-192+

Amygdaloidal trap d 7. 156-220

In Hole 7 coarse 1-2 mm. feldspars; 2 mm. chloritic blotches; occasional amygdules.

In Hole 6 it is similar. In Hole 5 the chances are there is faulting for while we have feldspathic trap to 580, then there are seams something like a contact dipping 45° to 33°, then for d 5. 587-589 it is spotted, and from d 5. 591-596 red decayed, perhaps the main slip, an amygdaloidal trap to 600; chloritic, feldspathic and amygdaloidal to 605.

(62.)

Amygdaloid d 5. 605-616

Red, passing into chloritic, amygdaloidal, feldspathic trap.

Trap d 5. 631-647

Fine grained; owing to the disturbance it is not at all certain to what this corresponds in Hole 7.

Torch Lake drill hole 6. 440 paces N. 33 paces W. Sec. 35, T. 56 N., R. 33 W. Vertical. This hole is altogether lapped by Holes 5 and 7.

(58.) Porphyritic melaphyre (3278)

d 6. 6-13

Feldspathic, slightly glomeroporphyritic.

(59.) Augite porphyrite d 6. 13-178 (3415)

(60.) Sediment d 6. 178- (1) (3416)

(61.) Feldspathic melaphyre

The indications of dips are:

15:15 ; 15:9; 15:18?; 15:4 and 15:5
at 6, 13, 25, 62, 180 feet respectively
averaging (leaving out the 15:18) about 29°.

Torch Lake drill hole 7. 770 paces N. 1705 W. Sec. 36, T. 56, R. 33. Vertical. Indications of dip are 165:79, i. e., 25°½. It will be as well to keep the reduction factor .9

(58.) Porphyritic melaphyre d 5. 387-415, d 7. 7-20
Amygdaloid with epidote and calcite, slightly porphyritic to d 7. 11.
Amygdaloidal trap to d 7. 17 and finer grained to d 7. 20

(59.) Augite porphyrite of Minong type.
d 5. 415-569; d 6. 13-178; d 7. 20-155
Described above.

(60.) Sediment missing in No. 7 (3416)
Only a foot. Is this the representative of
Conglomerate 8.

61. Amygdaloidal melaphyre 65
Amygdaloid d 7. 155-156
Small dip 22° and contact well marked.
Amygdaloidal trap d 7. 156-220
Massive, coarse feldspar 1-2 mm; chlorite blotches up to 2 mm., occasional amygdules. (3475)

62. Amygdaloidal melaphyre 46 (41)
Amygdaloid d 7. 220-244
Pink and green and white, passing into amygdaloidal trap.
Trap d 7. 244-266 (3516)

63. Amygdaloidal melaphyre 20 (18)
Amygdaloid d 7. 266-275
Amygdaloidal trap d 7. 275-286
(3534)

64. Feldspathic melaphyre 49 (44)
Amygdaloid d 7. 286-294
Red to 287, poor thence on.
Trap d 7. 294-335
To 296 a cobweb of feldspar, and an amygdaloidal trap to d 7. 300. At d 7. 305 are laumontite seams, and at 320 nearly vertical. Toward base the trap becomes massive, with iddingsite. The bottom contact dips about 31°.
(3578)

65. Melaphyre 13 (12)
Amygdaloid d 7. 335-342
Pink and gray, then maroon with yellowish white amygdules; at the base two feet epidotic.
Trap d 7. 342-348
(3590)

66. Melaphyre 18 (16)
Amygdaloid d 7. 348-352
Red for one foot then yellowish epidotic.
Trap d 7. 352-366
(3606)

67. Feldspathic melaphyre 13 (12)
Amygdaloid d 7. 366-369
Red top, yellow bottom, like the one above.
Trap d 7. 369-379
Feldspathic with cobweb of 1-2 mm. feldspar.
(3618)

68. Feldspathic melaphyre 12 (11)
Amygdaloid d 7. 379-382
Trap d 7. 382-391
Feldspathic

(3629)

69. Feldspathic melaphyre 34 (31)
Amygdaloid d 7. 391-395
Brecciated, red; dip 31°
Trap d 7. 395-425
12 -13
Feldspathic at 410-413 an amygdaloidal and epidotic streak.

(3660)

70. Feldspathic melaphyre 18 16
Amygdaloid d 7. 425-429
d 12. 13-15
Well-marked gray and white, with 2 feet epidotic at base in Hole 7.
Trap d 7. 429-443
d 12. 15-34
Laumontitic, amygdaloidal to d 7. 435, contact 45°?, then coarse 1-2 mm. feldspars, amygdaloidal also in 12 at 22-26.

(3676)

71. Feldspathic melaphyre 25 22
Amygdaloid d 7. 443-445
d 12. 34-40
Contact or flow streak? a few large amygdules below. Also in 12, scattered pink, white and green amygdules to d 7. 40
Trap d 7. 445-466
d 12. 40-53
Feldspathic. In 12 finer and darker.

(3698)

72. Feldspathic melaphyre 6 (5)
Amygdaloid d 7. 468-471
d 12. 53?-55
In 12 brecciated, epidotic.
Trap d 7. 471-474
d 12. 55-63?
Fine grained in 12, an amygdaloidal trap, probably not an independent flow.

(3703)

73. Feldspathic melaphyre 9 (8)
Amygdaloid d 7. 474-478
d 12. 63?-65? misplaced
Cf. also d 12. 77?-80?
Trap d 7. 478-483
d 12. 65-98 (or 80-98)
In 12 fine grained, feldspathic.

(3711)

74. 13 (12)

Amygdaloid d 7. 483-488
d 12. 98-107

Amygdaloidal trap d 7. 488-496 (or 506)
With pink cupriferous prehnite.
At d 12. 107 is a marked contact with pipe amygdules above.

(3723)

75. 38 (33)

Amygdaloid d 7. 496-506 or 506-
d 12. 140-143
With laumontite and calcite amygdules.

Trap d 7. 506-534
d 12. 143?-157
With occasional amygdules

(3756)

76. Feldspathic melaphyre 40 (36)

Amygdaloid d 7. 534-539
d 12. 157-161

Gray and white, poor in Hole 7. In Hole 12 with two feet epidotic from d 12. 159-161, and more or less amygdaloidal feldspathic to 171.

Trap d 7. 539-574
d 12. 161-194

All feldspathic trap growing finer from d 7. 539-568. In No. 7 vertical seams are much displaced by seams probably nearly parallel to the dip but dipping only 16°$\frac{3}{4}$. In No. 12 there appears to be a contact at d 12. 179 and a fine grained feldspathic trap below. Nos. 12 and 7, which below agreed well, here part company. The record is probably most disturbed in 7 near 539 feet.

(3792)

77. Copper bearing melaphyre? 31 (28)

Amygdaloid d 7. 574-575?
d 12. 194-195

In both holes the amygdaloid is poor, yet the contact well marked, then in No. 12 copper on vertical seams or columnar joints, and a little seam of datolite, prehnite and chlorite at d 12. 203 ft.

Trap d 7. 574-605
d 12. 195-226
d 10. 11-15

(3820)

78. Amygdaloidal melaphyre (30)

Amygdaloid d 7. 605-622
d 12. 226-232
d 10. 15-18

Very well marked contact dipping 28°, at first a black and white amygdaloid with a 2-foot epidote seam at the base. No copper was noticed in this but there was some in an epidote seam in the hanging at d 7. 602-3.

In d 12. 226-232 we also have a contact with pipe amygdules, and it is epidotic below, and then, too, in the hanging at 195 and 203 is

some copper. This seems a fair correlation and checks with the marked correlation of d 12. 426 and d 7. ·804.

In Hole 10 is a white and green amygdaloid.

Amygdaloidal trap d 7. 622-638
d 12. 232-259? (disturbed).
d 10. 17-45

Minute amygdules d 7. 624-635. In Hole 10 rather massive.

(3850)

79. Amygdaloidal melaphyre 25 (23)

Amygdaloid d 7. 638-646
d 12. 259-260
d 10. 42-45

Maroon, well-marked with dip about 11 in 7.

Much less plain marking like a flow band, with dip about 28 in 12.

In No. 10 an epidotic specked amygdaloid.

Trap d 7. 646-663
d 12. 260-287
d 10. 45-62

In Hole 7 it is an amygdaloid trap; in Hole 12 a feldspathic trap coarsest about d 7. 282; in Hole 10 it is a trap with an amygdaloid speck at d 10. 59.

(3873)

80. Amygdaloidal melaphyre 12 (11)

Amygdaloid d 7. -663?
d 12. 287-292
d 10. 62-65

In d 7. 663 is an epidote band, in No. 12 at 287 is clasolitic and dips 18°½.

Amygdaloidal trap d 7. 663-675
d 12. 292-305
d 10. 65-75

Amygdaloidal in No. 7. In No. 12 a fine grained feldspathic trap.

(3884)

81. Cupriferous lode, and amygdaloidal melaphyre 45 (40)

Amygdaloid d 7. 675-679
d 12. 305-309
d 10. 74-76 to 84 or 94

The contact in No. 7 dips 22° and the amygdaloid is epidote.

The contact in No. 12 dips 28° and shows copper; there is more on the foot.

In No. 10 from 76-84 is epidotic, and then to 94 amydaloid.

Amygdaloidal trap d 7. 679-720
d 12. 309-343
d 10. 76-94-111

In 7 a vein parallel to the hole between 679 and 705 may cut out an amygdaloid, but the streak of amygdaloid trap is probably a mere flow line in No. 12. In No. 10 however it is amygdaloid from 84-94, and again 97-102. Amygdaloidal trap d 12. 324-328.

At d 12. 337 is a calcite seam dipping 22°.

(3924)

82. Amygdaloidal ophite 21 (19)

Amygdaloid d 7. 720-730
d 12. 343-349
d 10. 111-113

Trap d 7. 730-741
d 12. 349-371
d 10. 113-138

The peculiar mixture of specked amygdaloid and mottled (ophitic?) trap comes in 12 at 349-371 and also in 10 from 113 down, and is notable. In No. 7 while there is much marked amygdaloidal trap with small amygdules there is also the effect of shearing at flat angles at 15° to 18°½ from d 7. 720 to d 7. 738 feet respectively. I wonder if they were peculiarly saturated with water in some way; cf. the ellipsoidal greenstones.

(3943)

83. Amygdaloid ophite, very peculiar mottles 29 (26)

Amygdaloid d 7. 741-750 or 755
d 12. 371-375
d 10. 138-141

At Hole 12 the contact is epidotic at 21°⅔

Amygdaloidal trap d 7. 755-770
d 12. 375-391
d 10. 142-161

In 7 banded and irregularly mottled and amygdaloid, also in No. 12 at 375 the amygdaloidal ophite bands dip 45° and there are ½ mm. mottles, at 388 the dip is less than 32°. The minute mottling reminds one of contact phenomena, spilosites, etc. Cf. also Hole 10. 113-120. Arcadian beds Nos. 110 and 111 and certain beds often associated with Conglomerate 6 and 7 seem to possess this peculiarity.

(3969)

84. Ophite 3 mm?, peculiar mottles 34 (30)

Amygdaloid d 7. 770-785
d 12.
d 10. 161-164

Trap d 7. 785-804
d 12. 391-421
d 10. 173-194

Peculiar rice-like elongate 3 mm. mottles at d 10. 172 and 178.

In No. 12 the mottles in coarse and fine bands, the coarse as large as 3 mm. came out well about d 12. 416. The banded, irregular mottles (dip 28°) show in No. 12 above 770 feet.

Epidote with a little leaf of copper at d 10. 173-175; also epidote and copper at d 12. 420-421.

Specked trap d 12. 421-426

Amygdaloidal base d 10. 190-194

(3999)

END OF CENTRAL GROUP?

85. Felsite tuff. Volcanic ash bed (1)

d 7. 804-805
d 12. 426′ 9″
d 10. 194-197

Apparent dip in No. 10 15°

At d 7. 800 is either a little felsite or sediment.

Base below base of Wolverine sandstone (4000)

Sp. 20584 at d 10. 195 represents this bed U. M. It is evidently a bed of felsite ash like the so-called Mesnard epidote. There are small fragments of porphyrite with lath-shaped feldspars to be sure. But most of it is either quartz or feldspar fragments, plagioclase or orthoclase, with very numerous fragments showing the conchoidal outlines of glass chips. The original fragments are outlined by different amounts and distribution of iron oxides. The bulk of the rock is now made up of a patchy mosiac of quartz and feldspar, with considerable disseminated calcite.

Sp. 20597 at d 12. 426 U. M. is not quite so clear. It might be a bit of felsite flow. Perhaps it is from a fragment. It is more charged with epidote and is traversed by a vein or fracture line from which the epidote spreads. There are a few minute phenocrysts of quartz and feldspar not over 1 mm. across.

This is a very important horizon as I correlate it with that of the felsites which occur to the north at intervals, the Mount Houghton felsite. Also compare the felsite on Sec. 4, T. 56, R. 32. It is noteworthy that the quartz porphyry which appears on the railroad track near by does not appear in any of the holes unless this represents it. I am therefore inclined to consider this its effusive equivalent, that being intrusive.

But if this represents the St. Louis or Bohemia conglomerate, (or the jasper belt of Figure 9, Volume VI,) and it is not so far from the line of strike, when we allow for the flat dip, then as we have found no group of beds corresponding to Conglomerate 8 and 6 of Portage Lake we are almost forced to believe that that group corresponds to this felsite horizon and the associated conglomerates of the end of the point, and the big ophitic series below down to the Baltic lode to a corresponding group of ophites which are cut by the Mt. Bohemia gabbro.

(86.) Amygdaloidal ophite 36 (33)

Amygdaloid	d 7.	805-818+	(13+)
	d 12.	427-445	(18)
	d 10.	197-211	(14)

Very marked in No. 7 all the way, specked in No. 12, with 3 feet epidotic at the base in No. 10

Trap	d 12.	445-463	This trap is characterized by fine and
	d 10.	211-233	coarse mottling; distinct even when no

larger than a pinhead.

Torch Lake drill hole 12. 560 paces N. 1320 W. Sec. 36, T. 56 N. R. 33 W. Vertical. This hole is lapped entirely by Holes 7 and 10. The dip by correlation with 10 on Stockly's section is only 14°, but this may be due in part to faulting. The average of observations of dip of flow and contact on the cores is, (omitting two very discrepant), tan-1 (150:71) or 25°½. Considering the possibility of faulting and veering strike, it will not be worth while to change the reduction factor from .90 to .97, as the difference is within the range of error, and the beds do not appear thinner in 12 than 7, though they are in 10.

						Thickness in 7.
(70).	425-443	12.13-	34	21		16
(71).	443-468	34	53?	19		22
(72).	468-474	53?	63?	10		5
(73).	474-483	63?	98	35		9
(74).	483-496	98	107-	9		12
(75).	7. 496-534	107	140?	33		33
		140?	157	17		
(76).	7. 534-574	157	179	22		36
		179?	194	15		
(77).	Copper bearing mel. 7. 574-605	12.194	226	32		(28)
(78).	Am. Mel. 7. 605-638	226	259	33		(30)
(79).	Am. Mel. 7. 638-663	259	287	28		(23)
(80).	Am. Mel. 7. 663-675	287	305	18		(12)
(81).	Copper bearing mel. 675-720	305	343	38		(40)
(82).	Am. ophite 720-741	343	371	28		(19)
(83).	Am. ophite 741-770	371-	391	20		(26)
(84).	Ophite 3 mm. 770-804	391	426	35	10.163-194	
(85).	Felsite tuff 804-805	426′ 9″			10.194-197	
(86).	Am. ophite 7.805-817	427+	445		10.197-211	

The samples seem to be a little misplaced in the boxes in Hole 12 and sheared in No. 7. No. 12 at 13 feet matches No. 7 at 425 feet fairly well. The extra thickness of the section in 7 may be due to flat shearing strike faults which can be seen about 535.

It is hardly worth while to try to correlate the rest of the beds of Hole 12 below the felsite tufa with those of Hole 10 in detail because they are both, especially Hole 10, much disturbed and crossed by shearing lines which are very heavy. Also they both consist of a set of beds which evidently are the same formation but are not separable into well-marked beds. They are a continual succession of amygdaloid beds with bubbles (amygdules) now fine, now coarse from 1 to 4 or 5 mm., mainly less than 3 mm. The original rock must have been more or less pumiceous. Occasionally as in beds (82) and (83) an ophitic texture with minute mottles seem to be combined. This is especially true at d 12. 623-636 which is thus far comparable with d 10. 352 to 358, d 10. 402 to 412, d 10. 460-474, d 10. 481-490, d 10. 497-501, and in Hole 11 the beds at the top, but one can not be sure whether these are repetitions by succession or by faulting.

As a whole, one would imagine that the lavas were more pumiceous and had perhaps lost less of their inherent water. The bottom of Hole 12 as a whole laps Holes 10 and 11.

d 12. 427=4000

The following are the notes from d 12. 448 down:

(87.)

(88.) Amygdaloid or amygdaloid trap to d 12. 448. From here on, characteristic amygdaloid and mottled beds -450 feet

Epidote 457

Bands of fine and coarse mottling 463

	Amygdaloid		466
	Epidotic		469
	Sheared at an angle of 45° and vertically. Amygdaloid coarse, and then characteristically fine and pumiceous,—one bed like this in the Victoria section. This continues with the amygdaloid mainly fine, but coarser at 522, 523, 526 feet down to		529
	Shearing occurs at a 45° angle.		
	Coarser amygdaloid		12.541-544
	Finer as usual, apparent dip of amygdaloid bands 18°½		12.546-553
	Then amygdaloidal trap, coarse amygdaloid at		12.564
			12.571-573
	Trappy		12.575-578
	Full of bubbles, pumiceous at		12.582
	Much seamed		587
	Coarse		593-596
	Finer		-601
	Coarse		-606
	Fine		-623
	Then amygdaloidal ophite ? mottles 1-2 mm.	at	629
	½ mm.	at	633
	Possible contact	about	12.636
	Cf.	10.443 and 372	
(88?)	Pumiceous amygdaloid	at	12.647
	Coarse specked trap with big round and also angular specks	at	12.661
	Here a shear much laminated	at	12.654
	Very pumiceous, fine amygdaloid	to	12.693
	Trap, specked	to	12.702

Since d 12. 427 is (4000 ft) below the Wolverine, this is about (4275)

Torch Lake drill hole 10. 360 paces N. 1150 paces W. Sec. 10, T. 50 N., R. 33 W. Vertical. This hole also is lapped pretty thoroughly by 7, 12 and 11. Correlating d 12. 426 with d 10. 195 would indicate a dip of only 14°. Reduction factor .97. Cf. in the Old Colony section the St. Louis conglomerate about 4500 feet below the Wolverine.

(78).	Am. mel.	d 10.	15-18	d 7. 605	
(79).	" "	10.	42-62		
(80).	" "	10.	62-74		
(81).	" "	10.	74-111? with copper?		
(82).	" ophite	10.	111-138		
(83).	" "	10.	138-161		
(84).	" "	10.	161-194		
(85).	Felsite tuff. Volcanic ash	10.	194-197	d 7. 805	
					(4000)

Apparent dip 15°, and as 200 in 7 correspond to 179 here, it is suggested that the beds are struck a little more at right angles. The reduction factor used in 7 was .9. If in 10 the beds are at 15° it should be .97 which will mainly account for the difference in thickness.

86. Melaphyre 36 (32)

Amygdaloid d 10. 197-211
3 feet epidotic at the base.
Trap d 10. 211-230

(4032)

87. Sediment, amygdaloid, conglomerate, red shale, with black and white amygdaloid scoria, much seamed and shattered. Dip 15°.

88. Pumiceous melaphyres

Amygdaloid d 10. 230-233
Trap specked d 10. 233-240
and amygdaloid.

Much seamed at 18°½ and at d 10. 240 a big seam at 16°½. All along from this on, partly perhaps owing to the seaming but more to the character of the beds, it is not possible to mark off exact flows, we have to do as in Hole 12.

The amygdaloid is poor	to	d 10.246
Then finer, pumiceous		10.248-260
A seam dipping 28° faults bands of amygdules dipping 22°.		
Amygdaloid is coarse from		10.260-263
Then specked trap, with decomposed bands across the hole, also a seam at 32° with the vertical.		
Much amygdaloid (dip 23°)		266-270
Trap, rotten with clay fluccan, dipping 34°		
Amygdaloid, decomposed (dips 13° or so)	to	10.282
Amygdaloidal trap	to	10.293
Pumiceous amygdaloid	to	10.302
Coarser (dip 21°¾)		303
Pumiceous amygdaloid	to	308

Of all the amygdaloids the characteristic feature is the very numerous bubbles generally less than 3 mm. across ranging from 1 to 4 or 5.

Amygdaloidal trap	to	10.311
Coarse amygdaloid	to	10.317
Pumiceous amygdaloid	to	10.319
Coarse amygdaloid	to	10.323
Specked trappy amygdaloid	to	10.333
Pumiceous	to	10.337

Then more compact with seams dipping 10° to 15°
Amygdaloid 10. 345-351

With veins at 45° and vertical; lots of calcite, little else secondary.

Mottled 1 mm. at 352
2 mm. at 355?

Amygdaloid yet with coarse and fine mottling in bands 10.358-364

Specked trap 10. 372

There may be a contact here.

Pumiceous amygdaloid (dip 20°)		10.370-380
Brecciated slide and fluccan		10.380-381
Fine grained specked trap	to	384
Amygdaloid	to	392
Big calcite seam (dip 26°½)	at	398

Mottled bands 1-3 mm., seams making a slight angle with the core

are faulted by slides nearly parallel to the dip (14°). The bands of specks and the size of mottles vary in short distances.

There are many big seams at 10.412

A heavy breccia seam nearly vertical, a fissure vein is crossed near 10.441

Amygdaloid, fine, with many nearly vertical seams to 10.457. (22° dip?)

Then bands of fine and coarser mottles from 1-3 mm., dip about 18°.

Fissure	at	10.470
Amygdaloid		10.476-481
Mottled 1 mm. at 483 ⅓ mm. at		10. 488
Marked pumiceous amygdaloid to		10. 497
Fine ½ mm. mottles		10.499
More coarsely ophitic but also amygdaloidal to the end		10.503

These banded amygdaloidal and at the same time mottled beds occur also in Hole 11, down to 705 feet, where it seems to pass into a block of Eastern sandstone. Definite correlations seem, however, impossible.

The bottom should be below the Wolverine about (4275)

Torch Lake drill hole 11. 300 paces N. 850 paces W. Sec. 36, T. 56 N., R. 33 W. This hole is close to the great Keweenawan fault, and in fact if I am not mistaken crosses it and encounters a block of Eastern or Jacobsville sandstone from 705 feet to 798 feet. The other beds it goes through are of the same type as Hole 10. The dip is quite flat in the Keweenaw beds, perhaps 10°. The general correlation is quite clear but individual correlations are far from certain. There must be a number of flows in the belt we call 88. It is possible the amygdaloid conglomerate at d 10. 233 may correspond to d 11. 86, but d 10. 195 is not represented. As the factor to reduce to true thickness is uncertain and probably makes only 3% difference *or less* it is not used.

(4032+)

(88). Amygdaloidal, pumiceous ophites, mottles 2-3 mm. d 11. 36

Amygdaloidal d 11. 36-42

3 mm. mottles 49

Gray and yellow-green -62

Full of irregular and chlorite seams and slickensides.

Angular breccia for d 11. 73-88

Amygdaloid conglomerate?

Dip 18°½ to 22°, also steeper seams parallel to the Keweenaw fault? dipping 51°.

Fine grained chloritic amygdaloid	d 11.	88-119
Banded ophite 1-3 mm.		-133
Amygdaloid and breccia seam		-150
Pumiceous amygdaloid, red and white and clasolitic		156-160
Amygdaloid, often coarse		
Amygdaloid, with clasolitic seams and beds. Dip 25° and shear dips 34° and more		-168

Amygdaloid, mainly fine to d 11. 256, with coarse streaks at		d 11. 174-177
		181-187
		194-196
		225-228
		229-235
		240-243
Seam at 18½°		
Ophitic banding with bright red (cf. iddingsite) specks.		
Cf. d 10. 402 flow banding 15°? at 235		
Amygdaloid coarse at 262		
Shearing at 22°		
Much red shearing and slickensiding, dip 31°.		
Thoroughly brecciated and trappy along	at	11.285
Banded 2 mm. ophite at		11.297
Contact at		11.307
Fine brecciated calcitic amygdaloid		
Sheared at		11.310
And thoroughly decomposed to		11.318
Much seamed at 26° to vertical at		11.322
Decomposed, seamed, with contact at 45° at		332
It is probable that we are getting abnormal dips close to the great fault.		
A dip of 36° at		11.338-348
Amygdaloid		11.348-358
Seams dip 15° and 59° in the same direction.		
Fine amygdaloid		11.358-362
Coarser amygdaloid		11.362-370
Mottles 1-2 mm. in trap		11.370-374
Fine amygdaloid		11.374-386
Coarser		11.386-391
Mottles 2 mm.	at	11.394
Seam		11.398-401
Amygdaloid		11.400-406
Mottles 1 mm. in trap		-412
Amygdaloid with many vertical seams and datolite crystals. Sp. 20586		11.412-429
Coarser		-437
Fine amygdaloid		-459
Seams at 45°		
Amygdaloidal ophite 2 mm. mottles		11.459-465
Possibly a contact		468
Amygdaloid, fine grained, dip of bands 18.5°		
Also seams at 15°		
Amygdaloid	to	11.539
Fine grained ophite to		11.543
Basal amygdaloid, dip 18.5°	to	11.545
Possibly a contact of flows here.		
Fine amygdaloid		11.545-547
Fine trap		-551
Poor amygdaloidal trap		-568
Amygdaloid		11.568-575

Amygdaloid, fine grained 1 mm. ophite		-583
Dip about 18°½		
Amygdaloid		11.583-596
Mottles 2-3 mm.		-608
Finer		-612
At this point a big seam about 15° from the vertical.		
Mottles at 622 and 628 feet 1 and 2 mm. respectively.		
There may be a contact at 633 feet.		
2 mm. mottles	at	11.660-664
Much seamed, nearly vertical or at 54°	at	668
A dark chloritic rotten trap		11.696-704

Seams vertical and at 56° and 18°½ therefrom.

Fault the Keweenaw fault about here (4700)?

89. Brown sandstone 11.705-794

The grains of sandstone show quartz and pink feldspar. They do not look like the intercalated Keweenawan sandstones but like the overlying Freda or Jacobsville sandstones. The color is white, mottled with brown. Cf. one of the Isle Royale holes; also one of the Lake holes; also one of the Challenge holes, and the Wyandotte holes.

The first core at 705 is somewhat one-sided, probably the other part (like that just above it) was chloritic. Pink (laumontite). Seams dip at 78[b] and 46°, the chlorite seams at 74°.

At first the dip is 11°. Seams (parallel to the fault?) at 59°.

The bedding is faulted at d 11. 714

Then the dip is 26°½, then 29°½

Near 794 the brown sandstone seems to dip 64°,—a pressure cleavage perhaps.

Fault.

90. Crosses fault and passes back into ophite seam, is at 34° to d 10. 798

This is evidently not in normal succession beneath the sandstone There is no basement conglomerate. It is of the same curious type at d 11. 646.

91. Much crushed, brecciated and distended amygdaloid. 798-854

This change is abrupt on a sharp clay plane dipping 25°. The rest is a slickensided amygdaloid, pumiceous like the low horizons of Holes 12 and 10, with red clay planes cutting it almost every way, e. g., dip 31° also 50°.

From d 11. 809-819 the breccia shows much shearing at about a 64° dip, with plain mottles.

§11. FRANKLIN JUNIOR. (FIG. 40.[1])

The neighborhood of Section 8, T. 55 N., R. 33 W., has been the center of exploration from the earliest times under the successive names of Albany and Boston, Peninsula and Franklin Junior.

[1] In envelope.

Sections were given in Volume 1,[2] further additions made by Denton in the Proceedings of the Lake Superior Mining Institute and still farther by Hubbard in Volume VI. But much more work has been done since and a compilation of the main section along the 4th level cross-cut of the Franklin Junior with various drill holes is given herewith as Figure 40, with a number of Rhode Island and Franklin drill holes brought into their proper geologic position regardless of their geographic position.

Franklin Junior Mining Company Section. A cross-section of this property is found in the Proceedings of the Lake Superior Mining Institute for 1894, prepared by F. W. Denton in a plate at the end of their Volume II, and again in Volume VI, Plate IX, of the Michigan Geological Survey Reports for L. L. Hubbard. The drill cores are, I think, in the Survey office. It is therefore not necessary to repeat these records in full but we may add additional data and enough from their records to combine into one consistent cross-section. There is one thing to which attention should perhaps be called. The dip of the "Albany and Boston" or Allouez conglomerate is taken as 52°. If it be taken as 48° as in Volume IX and customarily, the relations of Hole A and B will be somewhat changed. Diamond drill hole B was vertical and about five feet lower than the collar of No. 1 shaft in the Albany and Boston conglomerate, and 830 ft. from the foot of the conglomerate. It passes through 35 feet of drift. Then we have for Hole B reduction factor (cos 52°=) .608

1.	Porphyrite			(20)
	Amygdaloid	3	(1.8)	
	Blue trap	30	(18.5)	
	Cf. Arcadian	1	(32)	
2.	Amygdaloid	7	(4)	
	Trap	8	(5)	
	Cf. Arcadian	2	(8)	
3.	Amygdaloid	7	(4)	(36)
	Trap	52	(32)	
	Cf. Arcadian	3	(40)	
4.	Amygdaloid	3	(1.8)	(69)
	Trap	75	(46.2)	
		18	(11 to B 238 feet)	
	Cf. Arcadian	4	(42)	
5.	Amygdaloid	7	(4.3)	
	Trap	76	(46.8) to B 321 feet	
	Copper at B 272 feet			
	Cf. Arcadian	5	(46)	
6.	Amygdaloid	12	(7.4)	
	Trap	57	(35.1) Coarse	

This outcrops just N. W. of the Pewabic shafts, with a few large porphyritic crystals and more or less abundant bands glomeroporphyritic

Trap	30	(18.5)	Very fine black to B 437

This fine black trap came also in the 21st level-cross-cut at 457 feet and in Hole A at 501 feet, and is taken to be the immediate Pewabic lode

[2]In using such terms as Old Pewabic, Pewabic, etc., I refer to them as used in Volume I of these reports, in particular cross-sections, pages 81-86.

hanging. This Hole A was from the 8th level 20 ft. N. of No. 2 shaft and 503 feet below the collar.

7. Pewabic lode and foot (246)

Amygdaloid d A. 32 (20)	B.	437 to 469
	A.	501 to 476
		447-459 in cross-cut
Trap	A.	476-471
Amygdaloid	A.	471-451
Trap	A.	451-416

In the 21st level cross-cut we have the amygdaloid copper-bearing (9 ft.) lode at 447-459 and above it the fine grained trap. From 313-447 feet (133.5) feet (102) is all trap, at bottom band finer grained, then about 50 feet further on coarser, with prominent pink and green feldspar, and doleritic feldspar for some 22 feet. The prominence of the feldspar is partly due to alteration as the rock is wet and a wet seam from which a sample of salt water was taken (see analyses) dips with the foot about 40°. This is a heavy, well-marked bed. I suspect that the doleritic streak is the "green amygdaloid[1] of a record of Hole A in the L. S. M. I., 1894, as then the distances would agree very well, the whole belt A. 451-326 belonging together. The doubling of this amygdaloid at the end of A can be explained as due to some fault repetition,—a northward trending fault throwing the east side to the right or SE. perhaps.

The coarsely feldspathic character is plain also in the Arcadian section in d 5. 346-472; especially at d 5. 372 when the feldspar is 5 mm. long. Also d 6 down to 152; especially 57-98. The thickness also agrees. This is Arcadian 11.

The sections immediately above rarely agree exactly, and this is probably due to fault disturbances.

8. Amygdaloid 295-314 in cross-cut 19 ft.=15 ft.
d A. 326-301 25 =20

Poor, with rather uncertain relations,—it should perhaps be grouped with the heavy red amygdaloid band below.

9. Amygdaloidal melaphyre or melaphyres (103) to (46)
Red amygdaloid d A. 301-231=70 (65)
21st level cross-cut at 251-295=45 (33)
Trap d A. 231-181=50 (38)
21st level 234-251=16 (13)

S. 16 with occasional coarse porphyritic crystals and chlorite spots like Ss. 16441-16444 from Tamarack d 4. 2208-2416.

The heavy band of amygdaloids, at the top coarse pink and green amygdaloids with copper, seems to be identifiable in the Tamarack shafts. T 5 b 46. 2569-2630. They are wet, and some old shafts at the Franklin Junior were on them. If this is the old Albany and Boston amygdaloid then probably the identification in XV d is wrong. It seems to match the "Green Amygdaloid" of that section.

10. Ophite (52) to (99)

Amygdaloid	d A.	181-173=8 (6)
21st level	d A.	232-234=2 (2)
Trap,	d A.	173-115=58 (46)
21st level		232-131=101 (97)

[1]Not the "Green Amygdaloid" of Vol. I, Pt. II, p. 86, XV. d. The same amygdaloid will be in one place green, in another red, according to the stages of alteration.

In the cross-cut at 192 feet was a wet seam which I took to be one of decomposition dipping to the south. I took a sample of water (see Analysis, sp. gr. 1.045?). The amygdaloid at 232 is shaly and coarse, perhaps not the contact of a flow.

One must take 9 and 10 together to get a corresponding thickness of about 150 feet. This outcrops between the amygdaloid and conglomerate shafts.

11. The "Mesnard epidote" an ash or porphyry tuff.
 d A. 110-115=5 (4)
 21st level 98=103 (3)

S. 15 Fine grained, brown and yellow-green epidotic mixed, with a glassy conchoidal fracture. This very peculiar bed was also noted on Isle Royale hole VI. 81-91, and in the first Tamarack shaft, at 460 ft. It is really a volcanic ash, having had a large amount of soluble silica and showing conchoidal forms of volcanic ash. I think it may correspond to the Chippewa felsite of the Porcupines. There is no question about the correlation of the cross-cut at 103 ft. and A d 115, though there is some question about the correlation of the points at which the measurements of drill hole and cross-cut begin.

BEGINNING OF CENTRAL GROUP. END OF ASHBED GROUP.

12. Ophite
 Trap d A. 110-105=5 (4)
 21st level 70-98=28 (22)
13. Ophite the "Greenstone" (52 to 54)
 Amygdaloid d A. 105-85=20 (16)
 21st level 68-70=2 (2)
 Fine green trap d A. 85-37=48 (38)
 21st level 0-68=68 (50)
14. Albany and Boston or Allouez conglomerate (Marvine No. 15)
 Fluccan d A. 37-30
 Conglomerate d A. 30-0
 Shaft and drift about 15

This conglomerate has been extensively opened and is described in various reports, Steven's "Copper Hand Book" and Rickard's "Copper Mines of Lake Superior."

The thickness varies greatly in different parts of the mine.

The section is continued south in the 4th level cross-cut which begins 234.57 below the collar of the shaft and at the Kearsarge conglomerate is 197.72 below. The shaft is about 560 above Lake Superior (A. L. S.) Further description will be found in Vol. VI, Pt. II.

15. Melaphyre, feldspathic ophite (81)
 Amygdaloid -41 (31)
 Trap -108 (50)
 Arcadian 20
16. Medora lode and foot ophite (29)
 Amygdaloid 125 (13)
 Trap 146 (16)
 Arcadian 21
17. Ophite (Mandan?) (140)
 Amygdaloid 163 (13)
 Trap 203 (30)

Altered epidotic 221 (14)
Trap 334 (83) [1]seam of calcite 27 ft. from foot

18. "Ragged amygdaloid" and ophite? (41)
Amygdaloid 340 (5)
Trap -388 (36)
Arcadian 23

19. Ophite (51)
Amygdaloid -395 (5)
Trap -456 (46)
Arcadian 24

20. Houghton conglomerate (Marvine's No. 14) dip 49.5° (51)
Felsitic conglomerate -495 (29)
Sandstone -496 (1)
Amygdaloid conglomerate -524 (21)

21. Ophite (60)
Trap -602

22. Ophite (85)
Amygdaloid -617 (12)
Brecciated calcitic epidote, drift on it
Trap -713 (73)

23. Ophite (67)
Amygdaloid -718 (4)
Trap -730 (9)
Amygdaloid -747 (13)
Trap -800 (41)
Seamed

24. Ophite (90)
Amygdaloid -843 (32)
Decomposed,—slide striking northeast and southwest and dipping southeast
Trap -918 (58)

25. Ophite (92)
Amygdaloid -960 (32)
Drift
Trap -1038 60
Sp. 17300 Labradorite, augite, magnetite, olivine

26. Ophite (37)
Amygdaloid -1047 (7)
Trap -1086 (30)

27. Ophite (26)
Amygdaloid 1113 (21)
Trap 1120 (5)

28. Ophite (24)
Amygdaloid -1144 (18)
Trap -1151 (6)

29. Ophite (86)
Amygdaloid -1177 (20)
with amygdaloid conglomerate?
Trap -1264 (66)

[1]Misprint in Vol. VI— 85 for 83.

30. Ophite (70)
Amygdaloid 1269 (5)
Trap 1331 (48)
Seam 1332 (2)
Coarse, altered, doleritic, with *copper*
Trap 1353 (15)
31. Ophite (47)
Amygdaloid -1360 (5)
much altered calcitic bunching
Trap -1414 (42)
32. Calumet conglomerate (Marvine's 13) (36)
1414-1461
This is amygdaloidal, as it is also on the La Salle property, 4 in. fluccan, then sandstone largely.
33. Porphyrite, feldspathic melaphyre (92)
at 50 feet from the hanging slip on the N. side of the cross-cut carrying fluccan.
Amygdaloid -1464 (2)
Trap -1581 (90)
34. Porphyrite (42)
Amygdaloid -1634
with clay cavities
Sp. 17332 shows large olivines, augite granules. This amygdaloid has been much drifted on in the Calumet mine for drainage but has no copper.
35. Ophite (103)
Trap -1768 d D. 211
at 65 feet from hanging is a seam dipping 56° westward and other thinner seams showing faulting.
36. Feldspathic ophite (57)
Amygdaloid -1785 (13) d D. 211-247
Trap -1840 (44)
Verges on porphyrite, olivine and feldspar abundant
Shattered; seams dip about 45° east to southeast
37. Ophite (20)
Amygdaloid -1859 (15)
Trap -1864 (5)
38. Calumet amygdaloid and foot ophite (138)
Amygdaloid -1885 (16) d D. 361-398
Trap 2041 (122) d D. 398-468
Upper part shattered, lower part coarsely ophitic. This seems to be a very persistently marked sheet, being the first of five good-sized ophites above the Kearsarge conglomerate

Base, below Calumet conglomerate (451)
39. Osceola amygdaloid and foot ophite (98)
Amygdaloid -2060 (15)
Trap -2166 (83)
Supposedly opened by shaft 660 ft. N. 1200 W. of E. Q. P. of Sec. 8, which shows also 90 feet of overlying ophite
40. Ophite (64)
Amygdaloid -2171 (5)
Trap -2246 (59)

41. Ophite (125)
Amygdaloid -2252 (4)
Trap -2404 (121)

42. Ophite (92)
Amygdaloid -2414 (8)
Trap -2522 (84)

43. Kearsarge conglomerate (45)
Fluccan 16 in.; dip 52° to 52.5°
Porphyry conglomerate 39 ft.
Sandstone 4-½
Arcadian 49

Base from base of Allouez conglomerate 15 1971

44. Ophite
Amygdaloid -2581 (32)
Trap -(2632 by drill) 2621
The drill went from 2597, 232 feet beyond to 2829

Sp. 17909	5	slightly amygdaloidal, fine grained ophite
17910	10	doleritic, medium grained
17911	15	
17912	20	
17913	25	
17914	30	Finer grained than at 15

45. Ophite 5 mm. (141)
Amygdaloid (2632-2642 by drill)-2660
Trap (2808 by drill)-2798

Sp. 17915	at 35	amygdaloid with sandstone seam
	at 39	amygdaloid with sandstone seam
	at 47	coarse feldspathic dolerite
17916	55	coarse feldspathic doleritic
17917	60	coarse with clay seam
17918	65	coarse. Is much decomposed. The same decomposed seam and fissure and coarse amygdaloid was found in running the cross-cut at 2660
17919	70	
17920	75	flinty seam
17921	87	coarse In the cross-cut this very coarse amygdaloidal trap with pink and white amygdules was noted at about 2700 ft.
17922	93	coarser
17923	98	"
17924	113	coarser
17925	118	Long core, no amygdaloid in this
17926	127	coarse ophite about 5 mm.
17927	137	"
17928	142	"
17929	147	" veined
17930	157	
17931	173	
17934	179	
17935	184	
17936	189	
17937	191	

46. Feldspathic ophite? (73)
Amygdaloid d D. 2798-2805 (6)
17938 211 amygdaloid, compact fine grained
17939 218 amygdaloid, marked
17940 229 red indurated sediment, clasolite, did not show in
17941 amygdaloid at end of hole cross-cut, but cf. F. J. d 4 at 73
Trap d D. 2805-2890 (68)
at 2825 a 2 mm. ophite
Sp. 1 at 2856
47. Amygdaloid conglomerate (5)
d D. 2890-2897.5
Sp. 2 passing gradually into trap below, mixed with red sediment. This is very well marked also at the Wolverine mine cross-cut where it was opened by drifts. It also occurs in the Tamarack 29th level about (240) feet below the Kearsarge conglomerate. Cf. F. J. d 4. 73-81
48. Ophite (52.5)
Trap 2965.7
Sp. 3 at 2947.5 is an ophite
49. Ophite (123)
Amygdaloid to 2974.5 (7)
Trap 3125.5 (116)
Sp. 4 at 3024.5 with 3-4 mm. mottles (74) from bottom
5 at 3075.5 with 2-3 mm. mottles, darker and finer, 38 from bottom?
50. Melaphyre (25)
Amygdaloid -3148.1 (17)
Red and white with marked but small amygdules and clasolitic seams, copper reported.
Trap -3158.7 (8)
The fifth bed below the Kearsarge conglomerate at the Wolverine has also a heavy amygdaloid.
51. Melaphyre (24)
Amygdaloid 3167.6 (7)
Trap 3190.1 (17)
52. Melaphyre (14)
Amygdaloid -3201.1 (8.4)
-3208.6 (6)

Base below base of the Kearsarge conglomerate (482)
53. Amygdaloid to 3215.9 (6) (17)
Trap to 3230.9 (11)

Base below base of the Kearsarge conglomerate (499 ft)
At the Wolverine mine (§ 8 h) the 8th bed is (512) feet below
54. Amygdaloid to 3243 (9) (19)
Trap 3256 (10)
55. Amygdaloid to 3263.6 (6) (15)
Well-marked
Trap to 3267.3 (3)
Decomposed
56. Melaphyre (35)
Amygdaloid to 3288.311
Trap to 3320.3 24.5
The group of small flows leading to one strong amygdaloidal belt seems

to appear also in the Arcadian section 57-61 down to 605 feet below the Kearsarge conglomerate. Cf. amygdaloids 10, 11 and 12 of the Wolverine § 8 h.

57. Ophite feldspathic (55)
Amygdaloid to 338.8 (14)
Trappy with copper
Trap to 3391.8 (41)

Rather coarse and glomeroporphyritic to near contact. The rocks on the north side are not exactly alike as though the drift had veered a good deal in strike.

Sp. 6 is a 1 mm. ophite. Cf. F. J. 4. 139-200

58. Ophite (3-4 mm.) (51)
Amygdaloid to 3407.8 (12)
Trap to 3457.8 (38)

Sp. 7 of the amygdaloid is pink and green with rather coarse feldspar and amygdules also coarse. There is a seam dipping E. about 40°, 23 feet below the top of the trap, and striking about N. Cf. F. J. 4 Wolverine 11th level Belt 15.

59. First Kearsarge amygdaloid and porphyritic ophite (47)
Amygdaloid to 3468.8 (8.4)
Trap to 3518.8 38 plus
Sp. 8 is of the top 2 feet amygdaloid
Sp. 9 is 8 feet below the top and shows a little copper
Sp. 10 is the top of the trap
Sp. 11 is 17.7 from the top
Sp. 12 is 27 from the top

Sp. 13 is just above the base, toward which there is a marked columnar jointing perpendicular to the dip. There is here a genuine repetition.

60. Second Kearsarge amygdaloid and labradorite ophite (78)
Amygdaloid to 3529.4 (8)
Trap 3545.8 (13)-
Sp. 14 is 8 feet from the top of the amygdaloid

The cross-cut ended without reaching the Wolverine sandstone so that the thickness of the belt must be obtained by comparison with records of F. J. d 3, which shows a slide and a little Wolverine sandstone at 375 feet. This would project at 3407 in the cross-cut, but it is more northeast and evidently the strike is not at right angles to the cross-cut as it does not appear to be, but more north of northeast. The top of the Kearsarge is at d 3.250 making 125 feet thickness and a similar thickness is found at the Arcadian 63. (101?) and Rhode Island (112)

Owing to some disturbances it is not possible to weld the cross-cut and the drill holes into one continuous section. We therefore begin over again with the drill holes but give the corresponding numbers of beds.

It is worth noting that Arcadian belt 1 and Franklin Jr. belt 1 correspond very nearly and so do Arcadian 63 and Franklin Junior 61, so that in spite of thickening and thinning and dropping out of individual beds the average number and size is persistent.

F. J. drill hole 3 enables us to continue our numbering from 61 to the heavy ophite 66.

Franklin Junior drill hole 4. Dip of hole 45°. The dip of the beds being

about 48° the correction to reduce thickness along the hole tot rue thickness is negligible.

1. Overburden, till, 0-60
2. Ophite
   Trap d 4. 60-73 (13)
   mottling from 1 to 2 mm. growing less
(48?) 3. Sediment ? at 73
4. Melaphyre (67)
   Trap and sludge d 4. 73-139' 7" (67)
   Down to 81 it is largely a sludge of epidote, laumontite and calcite, then fine grained throughout, though growing finer with a few chloritic amygdules near the bottom.
   Sp. 17967 at d 4.84 has groups of small feldspars like a porphyritic margin
   17968 4.110
   17969 4.129
   17970 4.135
5. Glomeroporphyrite
   Amygdaloid d 4. 139-144 (5)
   Trap d 4. 144-200 (54)
   The amygdules have pink borders, green or white centers, and the bed is brecciated and coarse chloritic amygdules continue to 150 coarsest; near 176.
   Sp. 17971 d 4.154
   17972 4.170
   17973 4.177
   17974 4.195
(50?) 6. Feldspathic ophite Kearsarge hanging (133)
   Amygdaloid d 4. 200-207 (7)
   Trap d 4. 207-333 (126)
   Sp. 17975 at d 4.215
   17976 4.255
   17977 4.292
   17978 4.319
   The amygdaloid is largely in sludge, brecciated pink and black. Underneath it, from 212-214 the trap is light yellow-green, epidotic, then coarser to about 267 to 300 then finer to the base. At 251 there is an inclusion of a hard green fine grained amygdaloid spot. Toward the base it becomes red and faintly porphyritic. Beneath it the next 209 feet to the Kearsarge is disturbed and amygdaloidal. In the cross-cut too there are many small beds next beneath.
7. Disturbed belts
   Amygdaloid d 4. 333-340
   Marked red and white brecciated amygdaloid. Sp. 17979 at d 4. 338
   Trap to 356 chloritic, to 364 with signs of broken feldspar crystals like the Kearsarge foot, to 381 more massive and feldspathic, then finer, Sp. 17980 at d 4.360
   17981 4.378
   Amygdaloid d 4. 381-385?
   Trap, sludge and fine grained trap d 4. -394

Amygdaloid streak in the sludge d 4. 394-401

Trap d 4. -410, of a feldspathic melaphyre type, broken and sludge (411)

Amygdaloid with porphyritic feldspar ?—415 with prehnite calcite, etc., veined and broken-440, epidote and calcite seam-441

Trap fine grained seamed and broken-448 mottled ? to 560, finer with some amygdules and quartz to 463.

8. Slide or ash bed d 4. 463-475

This appears like a red shale with white flecks though the apparent dips are not at right angles to the hole but (2 or 3:10) presumably 11° to 17° more. At the bottom it seems to pass into a decayed amygdaloid. A section (Sp. 17982) of the red white flecked rock at d 4. 471 feet shows clear irregular areas of calcite, irregularly interlocking, with no unusual signs of pressure twinning, and spreading into the ground, which appears to be made up of small fragments and stained with iron oxide. Farther examination, however, seems to show that it is made almost wholly of epidote with a very little quartz and that not obviously elastic. All the material is highly angular and none of it can be said to be surely sedimentary. It might be a sediment steamed, full of bubbles, later filled with calcite. It does not look like a fluccan.

9. Amygdaloidal melaphyre (17)

Amygdaloid d 4. 475-486 (11)

Amygdaloid has white amygdules with pink borders and a nearly black ground

Amygdaloidal trap d 4. 486-492

10. Amygdaloidal melaphyre (28)

Amygdaloid d 4. 492-508 (with phenocrysts) cold gray (16)

Sp. 17983 at d 4. 493

Trap d 4. 508-520 (reddish, decomposed, fine grained, feldspathic (12)

Lens shows feldspar laths promiscuously

Sp. 17984 at d 4. 508

Sp. 17985 d 4. 515

11. Amygdaloidal melaphyre (7)

Amygdaloid d 4. 520-526 (6)

(pink bordered amygdules as above)

Trap d 4. 526-527 (1)

56? 12. Amygdaloidal melaphyre (15)

Amygdaloid d 4. 527-534

Trap d 4. 534-542 (8)

fine grained

59. 13. Labradorite ophite 1st Kearsarge amygdaloid and foot (49)

Amygdaloid d 4. 542-545 (3)

Trap d 4. 545-591 (46)

Sp. 17986 at d 4. 558

Sp. 17987 d 4. 557

Much broken to 556, with decomposed phenocrysts at 557-560; spotted growing coarser at 579; faintly ophitic. The Kearsarge amygdaloid lies I should think between 475 and 545. In some respects that from 492-508 correlates most closely.

(60). 14. Porphyritic ophite (3 mm.) 2nd Kearsarge amygdaloid (46+20?)
Amygdaloid d 4. 591-596 (5)
Trap d 4. 594-635+ (41) + (20?)

Red amygdaloid to 594 then greenish to 596, reddish to 601, then a greenish spot, at 604 and at 609 and 628 the large feldspar crystals are well marked 10 mm. long and over. The ophite mottling is perhaps 2-3 mm. across and over and the bed is very much like F. J. 3. 307

Sp. 17988 at d 4. 604
17989 d 4. 608
17990 d 4. 628

Franklin Junior drill hole 3. T. 55 N., R. 34 W. Dip of hole 48°. The dip of the beds being about 50° also the correction for true thickness is negligible, being not more than the possible veering of the hole.

1. Overburden, till, i. e., boulders sand etc., d 3. 0-110

(57). 2. Feldspathic ophite (38)
Trap d 3. 110-to 148

Begins coarse faintly ophitic 3 mm. then plainly finer with pipe amygdaloid from 147-148, and joints at 10° and 70° angle with the core. The bottom contact is at 65½° with the hole.

Sp. 17947 is at 144

(58). 3. Ophite 6 mm. (84)
Amygdaloid d 3. 148-158 (10)
Trap d 3. 158-232 (74)

Marked red amygdaloid to 150, then black and white to 158, then with coarse irregular chlorite and calcite down to (169)

Sp. 17949 at 160 feet, under the microscope shows amygdules filled with fibrous coatings of chlorite, and chalcedony in spherulitic aggregates; with labradorite laths; augite ophitic but scanty, about 3 mm. in diameter and abundant olivine pseudomorphs, changed into reddish micaceous matter and serpentine. There are no signs of phenocrysts.

Sp. 17948 is at 149
Sp. 17949 at 160
Sp. 17950 at 189
Sp. 17951 at 206 and 17852 at 217 respectively.

4. Kearsarge? Amygdaloid? (18)
Amygdaloid d 3. 232-238 (6)
Trap d 3. 238-250 (12)

Amygdaloid begins red with numerous, small, white amygdules to 234, then greenish epidotic with large white amygdules to 238, then spotted, decomposed with small chloritic specks and amygdules.

Sp. 17953 at 250 feet has fairly coarse feldspar, but there are no signs of porphyritic crystals.

(59). 5. Kearsarge amygdaloid and foot. Porphyritic ophite
Amygdaloid d 3. 250-254 (4)
Trap d 3. 254-260 (6) (10)

Hard, light gray amygdaloid with large amygdules of quartz

and copper, then a small streak of fine grained melaphyre with chloritic spots and labradorite phenocrysts.

(60). 6. 78

Amygdaloid d 3. 260-262 (2)
Trap d 3. 262-338 (76)

Amygdaloid is dark maroon, with calcite pink bordered amygdules, passing into light gray with large amygdules, and feldspar forms, often not fully showing quartz crystals in the cavities, then reddish fine grained with feldspar crystals 7 mm. and upward long. At 285 much seamed. At 298 it is darker, more plainly ophitic (5 mm.) and then grows finer.

This is typical Kearsarge foot trap and resembles F. J. 4 at 608. The Kearsarge amygdaloid must come between 232 and 260. Which band or whether the whole should be taken as its representative it is not easy to say exactly. Then the others may be considered mere streaks.

Sp. 17954 at 272 ft. and 17955 at 307 feet respectively, may represent it.

(61). 7. (26)

Amygdaloid d 3. 338-361 (13?)
Trap d 3. 361-374 (13)

Fine grained amygdaloid with 7 mm. feldspar crystals at first, then much broken and shattered with epidote and calcite-348; at 353 a little copper in a hollow epidotic amygdaloid which goes to 356; then a hard gray amygdaloid-358 and the amygdaloid begins to fade out but has some well-marked feldspars 20 mm. or so long. At 368 there is 1 mm. ophitic mottling with feldspars still.

Sp. 17956 at d 3. 345 is figured on Plate VII.

(62). 8. Slide 1½ "soft clay sandstone" 374′ 6″-376 (1½)

9. Wolverine sandstone, only a few inches at 376′ 9″ (½)

A light hard sandstone
Arcadian 64
Sp. 17957 at 380

(63). 10. Ophite 3½ mm. (74)

Amygdaloid ? d 3. 377-390 (13)
Trap d 3. 390-451 (61)
Begins chloritic fine grained, not properly amygdaloid

Trap mottles	3 mm.,	3½ mm.,	2 mm.
at	404,	410,	442

Sp. 17958 at 390
17959 410
17960 442

(64). 11. Ophite 4 mm. (84)

Amygdaloid d 3. 451-455 (4)
Trap d 3. 455-535′ 4″ (80)

Amygdules coarse of chlorite and calcite, a calcite and epidote seam nearly parallel, mottles 3 mm. and 4 mm. at 470 and 490.

Sp. 17961 at 467
17962 524 This is the specimen examined by R. T. Chamberlin for gas.[1] with the following results:

[1]The Gases in Rocks, 1908, pp. 20, 33 and 34.

	Analysis No. 85	Analysis 6 months later	Analysis 1 week later, after wetting
Hydrogen sulphide	0.00	0.00	
Carbon dioxide	1.31	1.33	0.52
Carbon monoxide	0.09	0.08	0.12
Methane	0.09	0.03	0.00
Hydrogen	2.34	0.43	0.12
Nitrogen	0.05	0.05	0.02
Total	3.88 vols.	1.92 vols.	0.79 vols

17963 534 feet showing contact

12. Sediment d 3. 535-537

There is one foot of scoriaceous conglomerate with a dark maroon basic sediment, making an angle of 71° with the drill core. Sp. 17963 at 534 ? shows contact

13. Fluccan at 37′ 10″. Cf. C. & H. A at 401 feet

(65). 14. Feldspathic ophite (7 mm.) (200±)

Amygdaloid d 3. 537-539

Trap d 3. 539-719-18?

Base below base of Wolverine about 360 ft.

This is markedly doleritic; so at 548, 565, 574, 577, 583, 593-598

Calumet and Hecla d A. 401-553 or 656

At 567 is epidotic, at 571 there is a calcite seam. Where it is "doleritic" it appears to have coarse amygdules and the feldspar is often 7 x 1 in size, and the chlorite interstices with occasional spangles of copper are well marked. On the other hand the augite is also often clearly recognizable.

The mottling is	5–7 mm.,	7 mm.,	3 mm.,	2 mm.
at	600-624,	652,	677-700,	700-719,

Sp. 17964 at 567 shows the epidotic phase

17965 596 " " doleritic phase

17966 616 " " very faintly mottled phase

This strikingly resembles the Arcadian bed No. 68 Arc d 2. 315-464+ and d 19. 43 to 139 which is 217 feet thick. Calumet and Hecla d A. 401-553 may be the same, and in the Wolverine cross-cut and Old Colony section it may be identified, with its base between 300 and 400 feet below the Wolverine. Cf. Central mine Belt 70 and the big bed in Manitou 7-5, S. This is either not in F. J. 2 or the very top which is most likely on Belt 9. Cf. 73.

An old shaft the "Kearsarge" shaft about 450 ft. N. and 1250 ft. W., S. E. corner of Section 8, T. 55 N., R. 33 W. is really about 3880 feet across the strike from the outcrop of the Albany and Boston conglomerate. From a vertical shaft 77 feet deep about 470 feet above Lake Superior drifts were run 582 N. W. and 238 S. E. These drifts were, then, not more than 30 feet or so above the 4th level cross-cut, but were about 1550 feet away along the strike. They were not accessible when I visited them but N. Martel reported that to the N. 37° (magnetic) W. they drove 100 feet to a vein on which is an inclined shaft magnetic strike S. 37° E. dip 48° or so (49-50°) which is 158 feet

deep. They drifted on this vein 50 feet. The cross-cut is 15 feet wide and struck the inclined shaft at a depth of 100 feet.

This vein extended from 100 ft. to 115 feet N. W. Then there are three or four little lodes especially one at about 300 feet some 25 feet wide

(12)
(77)

To the S. E. 113 ft. from shaft 12-foot vein taken to be Kearsarge Amygdaloid (86) (9)

It is pretty certain that this is a mistaken identification, but Hubbard and I found on the dump some Kearsarge foot trap so I think it was reached in the N. W. cross-cut, the Wolverine sandstone being perhaps absent as in F. J. 3 hole.

125-153	Trap	(22)
153-166	Vein	(10)
166-237	Trap	(55)

Near by are outcrops of scoriaceous conglomerate and feldspathic melaphyres. Cf. Beds 65 and below, and as near as one can make out from Martel's records the shaft is in a very heavy trap which might be (175) feet thick or more. This may be Arcadian bed (65) and Franklin Junior bed 68. It would agree in character, position and size. Then we should have:

(66). Melaphyre (31)
Amygdaloid (8)
Trap (22)
(67). Amygdaloid (10) (65+)
Trap (55)

Franklin Junior drill hole 2. Dip 42°. About at right angles to the formation, continues the section of F. J. 3 very nearly.

1. Overburden 47 feet

(66). 2. (2+)
Trap d 2. 47 (2)

base below base of Wolverine 360?

(67). 3. (14)
Amygdaloid to d 2. 254 (5)
Red and white
Trap to d 2. 263 (9)

(68). 4. Feldspathic ophite (5 mm.) (117)
Amygdaloid to d 2. 71 (8)
Trap to d 2. 180 (109)
Feldspathic, faintly ophitic
At 82 epidote seam, at 117 doleritic with 5 mm. augite mottles which are plainer toward the bottom, hardly visible at the center.

(69). 5. Feldspathic ophite (33)
Amygdaloid to d 2. 190 (10)
Decomposed, chloritic
Trap to d 2. 213 (23)
At 209 faintly mottled, at 212 to 213 fine grained, dark trap
Cf. Arcadian 70

(70). 6. Feldspathic ophite
Amygdaloid d 2. 218 (5) (67)
Amygdaloid like the Kearsarge but gradually passing into trap and pseudoamygdaloid at the base to 232.
Trap d 2. 270 (52)
Mixed with amygdaloid and pseudoamygdaloid, then coarser and ophitic, from 250 growing finer. Cf. Arcadian 71.

(71). 7. Amygdaloid conglomerate (5) (5)
d 2. 275 (5)
Cf. Arcadian 72 and 73

Base below Wolverine? (596)

(72). 8. Feldspathic ophite (59)
Amygdaloid d 2. 286 (11)
With clasolite seam at 280
Trap d 2. 334 (48)
Amygdaloidal, coarse feldspathic to 308 ft. then ophitic and finer
Cf. Arcadian 73

(73). 9. Feldspathic, doleritic, ophite 8 mm. (209)
Amygdaloid d 2. 343 (9)
Red
Trap d 2. 544 (201)
Often doleritic, at 407-417 dense green with sparse amygdules, an inclusion? Mottles at 368 to 400 8 to 3 mm., at 473 6 mm., at 505 8 mm., at 522 4 mm. Cf. Arcadian 74 and 75.

(74). 10. Red shale and conglomerate d 2. 544-548 (4)
Some copper in the shale. Cf. Arc. 76 and the Old Colony sandstone 966 to 980 feet below the Wolverine, respectively.
One bed of ophite may be omitted in this section.
Base below base of Wolverine

(861)

(75). 11. Feldspathic ophite (137)
Amygdaloid d 2. 552 (4)
Trap d 2. 685+ (133+)
Faintly amygdaloid and glomeroporphyritic in streaks with epidote, then grows coarse feldspathic.
Cf. Arc. 77

Franklin Junior drill hole 1

1. Trap d 1. 1-22 (22+)

(76). 2. Melaphyre (104)
Amygdaloid d 1. 22-30 (8)
with copper, veined
Trap d 1. 30-126 (96)
Feldspathic, few coarse amygdules to 45
Cf. Arcadian 78 or 80

(77). 3. Melaphyre (117)
Amygdaloid d 1. 126-153 (27)
Red and white brecciated and somewhat porphyritic to 144, then paler
Trap d 1. 153-243 (90)

Brown specks of altered olivine and green chlorite are abundant; it is full of chlorite seams at 75° to core and toward the base is dense and dark with copper on a chloritic joint. Cf. Arcadian 86.

(78). 4. Melaphyre (93)

Amygdaloid d 1. 243-272 (29)

Marked like that at 336-354 below

Trap d 1. 272-336 (64)

Glomeroporphyritic to 279 ft., then coarser but feldspathic and relatively finer grained, like the Central mine beds in Holes 3, 6, 5 and Torch Lake Belt 7 and thereabout.

(79). 5. Melaphyre (113)

Amygdaloid d 1. 336-355 (19)

Red and white brecciated and porphyritic, marked green at the end.

Trap d 1. 355-449 (94)

This is like 3, feldspathic fine grained to 388, then toward base very dark with plain specks of brown altered olivine, not ophitic, with occasional spots or bombs of pseudoamygdaloid.

(80). 6. Melaphyre (15)

Amygdaloid d 1. 449-455 (6)

Green epidotic, then red glomeroporphyritic

Trap d 1. 455-464 (9)

(81). 7. Copper bearing amygdaloid (43)

d 1. 464-479 (15)

Copper quite freely disseminated; looks worth developing

Trap d 1. 479-507 (28)

The brown specks of altered olivine and glomeroporphyritic character (feldspathic and not ophitic) make it like Torch Lake hole 9, Bed 5, the top of which there is 1486 feet below Conglomerate 9, and may be Belt 7 here. This would harmonize pretty well, with calling belt (76) d 2. 544-548 the Old Colony, because the distance of that below the Wolverine is about 100 feet short, and there is some uncertainty as to whether F. J. No. 2 does immediately continue No. 1.

Franklin Junior drill hole 6 whose location I do not exactly know was about at right angles to the formation.

1. Overburden (39)

(27). 2. Ophite 3 mm.

Amygdaloid F. J. d 6. 39-40

Trap 90

at 45,	54,	64,	76,	82 feet the mottles are
2,	1 to 4 in bands,	3,	2,	1 mm.

(28). 3. Ophite 3 mm.

Amygdaloid d 6. 90- 94

Trap d 6. 94-136

At 107 feet the mottles are 3 mm., and at 110 2 to 3 mm; then finer.

(29). 4. Brecciated amygdaloid or conglomerate

Amygdaloid d 6. 136-154

Dark and pink and brown, at 150 epidotic,

5. Ophite 4 mm.
Trap d 6. 154-284
At 171 epidotic and to this point spotted with amygdules, 230 coarsest 3-4 mm.

(30). 6. Ophite 3 mm. (68)
Epidote d 6. 284-288
Fine grained
Trap d 2. 288-352
At 330 4 mm. ophite

(31). 7. Ophite 4 mm. (47)
Amygdaloid d 6. 352-361
Trap d 6. 361-399
At 366 laumontite skeins; at 378 3 mm. mottles; at 395-398 veined, fine grained. There is evidently some disturbance, and this is quite probably not full thickness.

(32). 8. Amygdaloid conglomerate (Calumet and Hecla?)
Dark red sandy matrix d 6. 399-431 (32)
This has the same basic facies as in the Franklin Junior and La Salle properties,—not that of the Calumet and Hecla property.

(33). 9. Ophite 4 mm. (91)
Trap d 6. 431-522
at 449, 456, 464 feet the mottles are
1 to 2, 2, 3 to 4 mm., then finer

(34 & 35). 10. Ophite 5 mm. (51)
Amygdaloid ? d 6. 522-530 (124)
(175)
Brecciated, not really amygdaloid
Trap d 6. 530-697
The upper part is red and full of laumontite seams, with copper at 580 and 589 feet in an epidotic rock. Here is possibly a separate flow.
At 594, 612, 640 to 660, 673, 686 ft. mottles are
2, 3, 4 , 3, 1 mm.

(36). 11. Ophite 2 mm. (43)
Amygdaloid d 6. 697-710
Amygdaloid brecciated and red and white amygdaloid, the trap for 6 feet has large specked amygdules.
Trap d 6. 710-740
At 706 there are 1 to 2 mm. mottles.

(37). 12. Amygdaloid conglomerate
d 6. 740-769+? (29)
With red sandy matrix and down to 787 brecciated mixed and of doubtful nature. Calumet amygdaloid

(38). 13. Amygdaloid d 6. 769-787 (121)
Brecciated of doubtful nature
Trap d 6. 787-890
At 806, 817, 822, 824 feet the mottles are
1 to 2, 1 to 3, 2 to 4, 4 mm.
It is said to end at "hanging" of Osceola amygdaloid about 459 below base of Calumet conglomerate.

Rhode Island drill hole 4. About 80 feet from the Mineral Range R. R. and 500 feet from the Highway crossing, 1000 feet N., 1970 E. of the S. W. corner, Sec. 4, T. 55 N., R. 33 W., 527 (to 540) above Lake Superior. Dip 45°. From the south quarter post according to a map by M. Dennis is 187 feet in a direction across the strike to No. 3 hole. Thence to No. 2 is 157 feet, thence to No. 1 is 249 feet, thence to strike line of No. 4 is 488 feet, but No. 4 is 345 along strike line to N. E. Strike is N. 40° E. Plate IX.

To get the thickness, measurements along hole should be reduced about 2%.

1. Overburden, drift, hardpan and boulder (67)

(46). 2, Doleritic, feldspathic ophite (83+)
Trap R. I. d 4. 67-149
At 75 calcite seam nearly parallel to hole. Red specks, altered olivine abundant, doleritic texture common, feldspar 5 mm. long, chlorite blotch 2-3 mm., augite 8 x 2 mm., at 95 epidotic with seams of prehnite and copper, with a very faint mottling about 117.

(47). 3. Fluccan and red sediment d 4. 148′ 10-150′-1 (2)
Cf. Sp. 17940 and F. J. 3.173 feet

(47). 4. Glomeroporphyritic melaphyre (18)
Amygdaloid d 4. 149-156 (7)
Marked red, then gray and white with large coarse amygdules.
Trap d 4. 156-167 (11)
Glomeroporphyritic

(47). 5. Melaphyre, glomeroporphyritic (8)
Amygdaloid d 4. 167-168 (1)
With clasolitic matter; then gray and white
Trap d 4. 168-173 (5)
Glomeroporphyrite to 173
Amygdaloid d 4. 173-176- (3)

6. Amygdaloid conglomerate (3)
d 4. 176-179 (3)
Clasolitic matrix, dip 18° or so from being at right angles to core.

7. Melaphyre 16
Amygdaloid d 4. 179-181 (2)
Trap d 4. 181-195 (14)
Fine grained.

8. Amygdaloidal melaphyre (11)
Amygdaloid ? d 4. 195-201 (6)
Much ground up
Amygdaloid d 4. 201-206 (5)

(48). 9. Amygdaloidal conglomerate (5)
d 4. 206-211 (5)
With much sediment
In a way 3, 4, 5, 6, 7, 8 and 9 form one strong belt of amygdaloid conglomerate, but there seems to be a chance for fault repetition.

10. Melaphyre, glomeroporphyrite (10)
d 4. 211-221
Trap
Cf. Beds 4 and 5

(48). 11. Amygdaloidal melaphyre (6)
Amygdaloidal conglomerate d 4. 221-225 (4)
Trap d 4. 225-227 (2)
Fine grained
12. Amygdaloid 227-230 (3) (13)
Coarse pink and white amygdules, with prehnite and copper.
Trap d 4. 230-240 (10)
Dense
(49). 13. Ophite (22)
Amygdaloid R. I. d 4. 240-245 (5)
Green and white, becoming darker
Trap d 4. 245-262 (17)
2 mm. mottles?
(49). 14. Feldspathic ophite 3-4 mm. (88)
Amygdaloid d 4. 262-266 (4)
Greenish gray and white with prehnite and copper
Trap d 4. 266-350 (84)
The mottling is faint and only appears about 307 feet
Amygdaloid spot at 286, 288 etc.
At 313, 334 feet the mottles are about
3-4 & 2-3 mm.
(50). 15. Amygdaloid conglomerate (6)
d 4. 350-356
Well-marked
(52). 16. Amygdaloid d 4. 356-366 (10) (35)
Gray and white, poor at base, but a well-marked, red, glomero-porphyrite with small pink feldspar laths 1 mm. across.
Trap d 4. 366-391 (25)
At 372 yellow with epidote, at 372.8 is still glomeroporphyritic then rather coarse; at 373.3 clasolitic seam; coarser at 381-383; at 389 amygdaloid spot then finer; somewhat amygdaloid.
(53). 17. Melaphyre (17)
Amygdaloid R. I. d 4. 391-397 (6)
Gray and white, then poor chloritic
Trap d 4. 397-408 (11)
Compact with a 2 mm. mottling, perhaps due to the feldspar.
Basal contact marked.
(54). 18. Melaphyre (21)
Amygdaloid d 4. 408-413 (5)
At top large amygdules with prehnite, quartz, epidote and a trace of copper; below poor.
Trap d 4. 413-429 (16)
Slightly mottled (2 mm.) at 421, then finer
(55). 19. Melaphyre (8)
Amygdaloid d 4. 429-434 (5)
Trap d 4. 434-437 (3)
Chloritic
(56). 20. (24)
Amygdaloid d 4. 437-446 (9)
Red and white,—ground to sludge for the first 5 feet, poor below.
Trap d 4. 446-461 (15)

21. (44?)
Amygdaloid d 4. 461-464 (3)
Brecciated red at top, then gray
Trap d 4. 464-505? (41)
Chloritic with amygdaloid bands or bombs—not flow contacts—at 471 and 480, fine grained, faintly mottled (at 494 2-3 mm.) but specked.

22. (7)
Amygdaloidal melaphyre
Amygdaloid d 4. 505-12 (7)
Green (epidotic?) with white amygdules like a bomb, perhaps base of 21.

23. Amygdaloidal conglomerate
At 512 feet a few inches

24. Amygdaloidal melaphyre? (2)
d 4. 512-514
Gray and white, lower foot poor

25. Sandstone d 4. 514-516
Gray, epidotic, with copper, dip 9° to 14° from being at right angles to the core. If this correlates with R. I. 7 at 148 ft., and 746 feet correlates with R. I. 1 at 551, (and of the latter I am the more sure) there is evidently a repetition of some 160 feet there or elision here.

26. Amygdaloidal melaphyre? (6)
d 4. 516 to 522
Green and pink amygdules on dark ground growing dark with white pseudoamygdaloid specks.

27. Amygdaloid conglomerates? (1′ 8″)
d 4. 522-523′ 8″
With gray sandstone cement like 25
From 512 to 535 is very likely all the top of the bed below.

28. Trap ? d 4. 523.8″-535
Fine grained with dark, chlorite amygdules and red clasolites to 527.5. About 529 a seam of mohawkite (copper arsenide) 2 mm. wide, below this compact with chloritic flecks.

(58). 29. Feldspathic ophite (5 mm.) (76)
Amygdaloid d 4. 535-541 (6)
Contact 22° away from right angles to core
Typical gray and white amygdaloid with copper
Trap d 4. 541-611 (70)
Faintly mottled at 559, 576, 582, 589, 597, 612
4, 5, 4, 3-4, 2-3,
Epidote spots at 562 and 564.

(59). 30. Amygdaloidal melaphyre (17)
Amygdaloid d 4. 612-624 (12)
Red and white, then gray and coarse
Trap d 4. 624-631 (6)
Decomposed and amygdaloidal throughout with green amygdules at the base.

31. Amygdaloid R. I. d 4. 631-634 (3) (8)
Marked

Trap d 4. 634-639 (5)

Fine grained fissured with calcite and dark chloritic contact marked.

(60). 32. Kearsarge lode No. 1 with labradorite ophite (86)

Amygdaloid d 4. 639-650 (11)

Red with white amygdules, crystallized quartz and calcite and faint signs of copper, with epidote and porphyrite labradorite. Poor from 644 down

Trap d 4. 650-725 (75)

The crystals of labradorite are marked 15-20 mm. long and seem to grow coarser; about 668 the mottling begins to be visible.

At. 668, 678, 698, 706 feet mottles are

3–5, 4–5, 4, 3 mm. across respectively

At 719 it is distinctly finer and at the bottom it is very dense, bringing out the phenocrysts beautifully, and there seems to be a pipe amygdule.

(61). 33. Kearsarge lode No. 2 with labradorite ophite (19)

Amygdaloid R. I. d 4. 725-735 (10)

Brecciated, almost a conglomerate with conspicuous porphyritic crystals and laumontite.

Trap d 4. 735-746 (9)

Big 20-22 mm. phenocrysts of labradorite and 1 mm. ophitic mottles.

(62). 34. Wolverine sandstone No. 9 d 4. 746-752 (6)

With sediment, slips, copper, prehnite and epidote

Correlate Caldwell d 1. 281-288

(63). 35. Ophite (57)

Trap d 4. 752-809+1 (57+)

Fine grained at beginning like the lower part of a flow; some prehnite and copper to 757. No porphyritic crystals.

At 766, 771, 784, 788, 796, 801-809

2–3, 2–3, 2–3, 2 fine grained

Rhode Island drill hole 1. 390 feet N., 2270 feet E. of S. W. cor. Sec. 4, T. 55 N. R. 33 W. 593 feet across the strike from the S. quarter post. Elevation 515 above Lake Superior. It is about 500 feet from No. 4 on the side of a 10-foot terrace at the head of a ravine to the S. W. Dip about 45°. Correlations with Rhode Island No. 4 will be made by subtracting about 200 feet. But this implies a very considerable fault (See Pl. IX.) between 4 and 1 since from 1 to the line of strike of 4 is 488 feet, the elevation is not very different, so that the difference should be about (488 x sin dip) 360 feet or so. Thus, the difference is 160 feet less than might be expected corresponding to a fault with a horizontal displacement of the northeast side to the north of about 215 feet.

The correlation between drill holes 2 and 1 which are across the strike from each other is such that it is probable that the fault passes between 2 and 1, Hole 2 being on the same side of the fault as Hole 4. Compare also the note on Bed 25 of Hole 4. This would determine the strike of the fault as not far from N. 26° W. Any reasonable correlation of drill holes 2 and 1 gives much too steep a dip. The samples of 1 have not been all looked over by Lane. The record runs as follows:

1. "Overburden 95
2. Trap to 142′ 10″ (48)
3. Epidote to 146′ 5″ (6)
Sandstone to 148′ 3″
Cf. R. I. 4 at 73 ft., and also R. I. 4 at 514 ft.

This latter correlation, while not in harmony with those below, would give a dip fairly in harmony with that from 4 to 2 as though the top of 1 might not be displaced in relation to R. I. 4 at 514

4. (92)
"Vein and trap to 153′ 2″
"Epidote 153′ 8″
"Vein 156′ 10″
"Trap 177′ 2″
"Epidote 179′
showing very pretty samples of copper
"Trap 187′ 10″
"Epidote 191′ 3″
"Trap 208′ 3″
"Trap 240′ 1″

5. "Vein first 254
"Mixed vein and trap 260′ 6″
"Epidote; a little copper 266′ 7″
"Trap 287′ 10″ (34)

6. "Vein 288′ 3″
"Trap 304′ 11″ (17)
"Vein; a little copper 305′ 11″
"Trap 342′ 6″ (38) Cf. R. I. 4,
(59). 541-611
A coarse ophite

(60). 7. "Vein second to 361′ 8″ (19)
"Trap to 373′ 8″ " (12) (31)
This is the Kearsarge foot, with large porphyritic labradorite
(61). "Vein to 374′ 8″
"Trap (5″ of epidote showing copper) 383′ 1
"Trap to 499′ 6″ " (125) (157)
The sample is the porphyritic ophite, the Kearsarge foot.
From 465 to 478 is a marked 3 mm. ophite. Cf. R. I. 4. 706
"Mixture of trap and vein"
A little copper to 532′ 10″
At 502 white and green, and laumontitic to 507
At 512 fine grained

8. (39)
Copper bearing amygdaloid to 529-532
(61)? "Trap to 550′ 6″ "
2 mm. ophite at 547
"Trap to 551"

(62). 9. Wolverine sandstone? No. 9
"Conglomerate showing copper 551 to 551′ 6″ " (1)
Cf. R. I. 4.746

(63). 10. "Trap -579
"Trap and epidote -580′ 7″
"Epidote -584′ 7″
"Trap -614′ 8″ " End (63)

Rhode Island drill hole 3. 110 feet N., 3280 feet E. of S. W. corner of Sec. 4, T. 55 N., R. 33 W. and 187 feet across strike from S. Q. P. of Sec. 4. It was put down at an angle of 56° to the N. 50° W., through 90 feet of overburden with the idea of following the lode. It went out of the lode but kept on for 500 feet. It was probably directed too steep, not allowing for the fault just mentioned.

Rhode Island drill hole 2. 210 feet N., 2450 feet E. of S. W. corner of Sec. 4, T. 55 N., R. 33 W. 157 feet across strike from 3 and 344 feet from the South quarter post. Elevation about 521 above Lake Superior (6 feet higher than No. 1). Dip 45° for hole. The correlation of d 2. 157 and d 4. 746 implies for the strata a dip of 52° 50′.

1. Overburden 110
2. Ophite
   Trap to 112.6

(60). 3. Kearsarge amygdaloid and labradorite ophite (20)
   Amygdaloid R. I. d 2. 111.6-117.5 (5)
   Trap d 2. 117.5-131 (15)
   Broken, but with characteristic feldspar crystals an inch (25 mm.) long on a fine grained ground. This does not seem to be Belt 62 in full, perhaps cut out by the fault.

(61). 4. Kearsarge amygdaloid and labradorite ophite (26)
   Amygdaloid d 2. 131-136 (5)
   Red and green epidotic
   Trap d 2. 136-157 (21)
   Trap and coarse amygdaloid with porphyritic labradorite an inch long. The amygdules have heavy chlorite borders, white centers.
   Matches R. I. d 4. 725-746.

(62). 5. Wolverine sandstone No. 9 (6)
   Epidotic conglomerate d 2. 157 to 159
   Then finer cold gray to 160
   Good conglomerate core to 163
   Matches R. I. d 4. 746-752

6. Vein or fault? (15)
   Broken sludge and amygdaloid vein 163 to 178 end.
   This may be part of the fault separating 1 and 2 if it has a strong easterly dip.
   If R. I. d 4. 746=d 2. 157 then as 4 is 6 feet higher and at an angle of 45° a point at 8 feet down in R. I. 4 will be at the same elevation as R. I. 2 at 0, and a point at R. I. d 4. 589 feet will correspond to the beginning of No. 2. The distance at right angles to the general strike between R. I. 4 at 8 or R. I. 2 at 0 would be 731 feet and the consequent dip=tan-1 [illegible]=52° 50′
   This is quite a reasonable dip. Rhode Island No. 1 shaft dips 50° 16′. No. 2 dips $49°\frac{2}{3}$, and the dip on the Kearsarge conglomerates in the long cross-cut is 52.5°.
   But R. I. d 1 seems to have the Wolverine at 551 feet, and is 6 feet lower, and is but 249 feet from 2. Hence a point in No. 1 at 8 feet will be (249-8) 241 horizontally from No. 2 at 0 while the corresponding point of the beds to No. 2 at 0 feet will be in No. 1 at 394 feet, and that would be nearly under it but actually a little

S. E. about 12 feet. So that the dip would be steep to the southeast. Such a dip is out of the question and then if the fault did not incline eastward itself No. 2 would have to be crossed by it were it not for the 110 feet of drift. It may be crossed anyway at 117 to 126 feet.

§12. ARCADIAN (FIGS. 41 AND 42.)[1]

This was one of he earliest complete sections and was done under the direction of R. C. Pryor for the Arcadian Copper Company, (A. C. Burrage, Pres.). The locations of the holes have not in all cases been precisely surveyed. The elevations are about 540′ A. L. S. in T. 55 R. 33.

They are approximately as follows:

Above Lake Superior	Elevation	Feet N.	Feet	From Point	Section
5	513	4130	830 E	S. Q. P.	18
6	525	3760	700 E.		
8	535	2600	420 W.		
7	522	2360	970 W.	S. Q. P.	18
1					
2					
19			At 2700 N. W. across strike from No. 2 shaft		
20		1830	230 W.	S. Q. P.	19
21		1640	236 W.		
22					
4	N. W. end of 8th level cross-cut which was 432′ in[2]				
3	S. E. " " " " "				
					30
9			480 S. E.	across strike from Douglas shaft	
10			939 S. E.	across strike from Douglas shaft	
11			1210′	across strike from Douglas shaft	
12	200′ N. E. of No. 11		1250′	across strike from Douglas shaft	
13	200′ S. E. of No. 11		1200′	across strike from Douglas shaft	
14			1748	across strike from Douglas shaft	
15			2038	across strike from Douglas shaft	
16			2518	across strike from Douglas shaft	

The last set of holes from 9 to the end were located by a set of coordinates parallel to the strike of the lode at the Arcadian N. 37° 49′ E. . . . . (R. C. Pryor)

[1]In envelope. This is earlier drilling; not that done by the reorganized company. See Appendix, and also Plates IX and X.
[2]These holes are shown on Fig. 42, but their numbers have been accidentally omitted.

These locations were derived from R. C. Pryor and correspond to the section in Figure 42. But Supt. Shields says he thinks 7 was down near the Albany and Boston conglomerate then and above 8, in which case it might cut the Houghton conglomerate. He also says that they sank on the "St. Mary epidote"—the Mesnard epidote of some reports (See Vol. I, Pt. II, p. 85). It was 51 feet over to the Albany and Boston, which was 72 feet thick.

Abstract of Arcadian Cross-Section.

Belt No.		Feet
1.	First bed, Hole 5 (32)+	
	Base of first bed above the Alllouez 15 glomeroporphyrites, and Tobin porphyrites	(760)
	Base of Quincy Hanging and Tobin, Hole 6, 35-57 glomeroporphyrites	(509)
	Base of St. Mary's epidote	(80)
19.	Allouez conglomerate, is Albany & Boston, is Marvines No. 15.	
	Beginning of Arcadian Hole 8 about (820) below the Allouez base.	
38.	Base of Calumet & Hecla conglomerate (8.358) about 1100 feet below the Allouez base.	
	Base of Osceola hanging	about 1507 feet
	Four heavy ophites between	
	Base of Kearsarge-North Star	about 1942 feet
42.	The Kearsarge-North Star conglomerate is apparently. Marvine's Nos. 10, 11, 12.	
	Hanging of Kearsarge is a heavy ophite d 1. 262-385. Above is quite amygdaloid.	
	Base of hanging of Kearsarge amygdaloid (726 feet) below the base of the Kearsarge.	
	Kearsarge foot is a markedly plagiophyric ophite (109) feet thick.	
	The base of the Wolverine sandstone is (866) feet below the base of the Kearsarge. (2835) feet below the Allouez base.	
		(2835)
64.	The Wolverine sandstone is probably Marvine's No. 9	
	Down to 76 *feldspathic* ophites with frequent *scoriaceous* amygdaloids and a tendency to glomeroporphyritic texture, much better developed in the Torch Lake and Central Mine section.	
76.	Epidotized copper bearing sandstone (968) feet below the base of the Wolverine sandstone.	
	Arc 20 has doleritic and inclusion beds down to 45; below the base of the Wolverine sandstone.	(1650) feet
92.	Down to 92 hanging of Arcadian mainly ophites; below the base of the Wolverine sandstone.	(2450) feet
	Ophites and inclusion beds	
106.	Conglomerate 8, base below the base of the Wolverine sandstone	(3015) feet
	below the Allouez base	(5840) feet

112. Sediment with fine ophite above	
below Conglomerate 8.	(227) feet
114. Epidotic sandstone, Conglomerate 7?	
below Conglomerate 8	(267) feet
117. ?	
120-125. Feldspathic melaphyres; and amygdaloids with copper.	
126. Conglomerate 6 ?	
below Conglomerate 8	(815) feet
129. Conglomerate fault repetition of above ? or 5?	
below Conglomerate 8.	(955) feet
132. Fine grained ophite	
134. Scoriaceous conglomerate	
below Conglomerate 5.	(395) feet
136, 139, 141, 142, 144 all are ophites with scoriaceous tops	
146. end of section	
below Conglomerate 5	(945)
below Conglomerate 8	(1900) feet
below Conglomerate 9	(4915) feet
below Conglomerate 15 the Allouez	(7740) feet
Total column 760+7740=8500	

These drillings were examined by Mr. R. C. Pryor, E. M., the engineer at the time, and a record made and a cross-section constructed. I was also permitted to examine both the cores and Mr. Pryor's notes on the same, through the kindness of Mr. A. C. Burrage, which gentlemen with Mr. R. H. Shields, the Agent, and Mr. Edward Shields I am glad to thank for favors and assistance.

Mr. Pryor, of course, examined them with particular regard to the different amygdaloids and the occurrence of copper. I naturally supplemented his work by paying more especial attention to the different belts of trap, their petrographic character and grain, and have tried to separate the column into the different lava flows. As, however, it is not possible to determine in the boxes which have been rehandled the exact depth at which a given drill core came I have often used Pryor's figures in cases in which I was sure that we were referring to practically the same belt. Otherwise there may be two or three feet difference, probably sometimes to be accounted for by the fact that the bottom of the flow is often slightly amygdaloidal for two or three feet or more. In such cases Pryor would naturally take the top of the amygdaloid two or three feet higher than the top of the flow so that by taking his figures in such case I make an error of a couple of feet perhaps. However, when we consider possible errors in the course of the drill hole, and the dip of the lodes, this becomes an inappreciable error. I do not repeat here all Pryor's notes on the amygdaloids, or the occurrence of copper.

In the first place I give the name of the flow, the interval for each drill hole that I assign to the flow, usually consisting of a certain amount of amygdaloid and a certain amount of trap, preceded by Arc. and the number of the drill hole, thus, Arc. 5, 1-8. Next follows in parenthesis the thickness of the flow as computed and often the total distance from certain planes of references, the base of Conglomerate 15, the Allouez or Albany and Boston being the most important one. Next follows further notes, comparisons and descriptions.

The drill holes run in order, taken from northwest to southeast as follows: 5, 6, 8, 7, 1, 2, 19, 20, 21, 22, 4, 3, 9, 10, 11, 12, 13, 14, 15, 16.

No. 5 was started about 900 feet horizontally across the formation from the foot of the St. Mary's epidote lode. (950 feet on a line making with the Albany and Boston conglomerate's strike an angle of 87° 20′.) It is only 1,000 feet from Marvine XV.[1] There was 8 feet of stand pipe to bed rock.

1. Melaphyre porphyrite.
   Arc. 5, 8-40 (32)
   Light gray porphyritic feldspar, dark green dots of delessite 1 to 2 mm., brown matrix. This is probably not the typical olivinitic augite porphyrite with idiomorphic augite, like the ashbeds proper, but the intermediate type like Marvine's Eagle River Section bed No. 87. This is of the same type as the 226 feet of melaphyre reported by Marvine 740 feet above the top of the Albany and Boston Conglomerate 15, on the St. Mary's property Section XV.
   Base above the Albany and Boston Conglomerate 15, about[2] (760)
2. Melaphyre porphyrite.
   Arc. 5, 40-48 (8) ? (8)
   With two feet of dense massive epidotic amygdaloid at top, base uncertain. Cf. Marvine's 4 amygdaloid 14 melaphyre.
3. Melaphyre porphyrite.
   Arc. 5, 48-52 Amygdaloid (40)
   52 to 89 trap
   Conspicuously glomeroporphyritic, with occasional larger phenocrysts.
4. Melaphyre porphyrite.
   Arc. 5, 89-93 Amygdaloid
   93-132 trap (42)
   Base above the Albany and Boston conglomerate probably more than (670)

   Amygdaloid of calcite chlorite and epidote extending down below the fine grained amygdaloid at the top.

[1]References to Marvine or to his section in Vol. I of the Reports of the Michigan Geological Survey, Part II, Chapter V.
[2]At an angle of 50°,—more if the dip angle is steeper; at 52° 3/4 791.

5. Melaphyre glomeroporphyrite, several flows?
   Arc. 5, 132-178 (46)
   Amygdaloid at the beginning and at 144, 153, and 161 feet. Rarely there are large feldspar phenocrysts, but the flow is generally glomeroporphyritic, at 172 is a light green streak. Calcite, laumontite and epidote occur in the amygdaloid.
6. Melaphyre glomeroporphyrite.
   Arc. 5, 178-190 (12)
7. Melaphyre glomeroporphyrite, two flows? or slip.
   Arc. 5, 190-200 amygdaloid
   200-260 trap (60-)
   Finer grained at 215 to 227, and veined at 232 feet. Glomeroporphyrite, with larger phenocrysts of feldspar also. Arc. 5, 232-242 is like the trap of the Franklin dump and the beds at the top of the drill hole VI Isle Royale, which are supposed to be between 300 and 400 feet above No. 15. Cf. Tamarack 5b 33=T 4b .27 and the glomeroporphyrites beneath it down to T 5b 48. At Arc. 5, 215-227 it appears finer; at 232 much veined.
8. Melaphyre porphyrite.
   Arc. 5, 166-280 amygdaloid (14)
   Coarse feldspathic about 272.
9. Melaphyre porphyrite.
   Arc. 5, 280-300 amygdaloid
   300-320 trap (40)
   Above the base of the Albany and Boston Conglomerate 15 about (530)
10. Melaphyre glomeroporphyrite.
    Arc. 5, 320 to 324 Amygdaloid (21?)
    -324-341
    Arc. 6, between 35 and 57
    This is not a very well marked bed and may be merely a gush of the large lower flow beneath it. Cf. the beds 11 (cupriferous bed) feet thick 25 and 9 feet thick of Marvine's XV, which in Denton's section at the Peninsula are 15.8, 3.9 and 19.7 feet respectively, their top being 512 feet, respectively 378.9 feet above the Albany and Boston. The boundaries of the beds above are also very uncertain and agree neither in this section, nor in the Peninsula (Franklin Junior) nor the old St. Mary's. I give them comparatively, giving from the lower beds up, from left to right.

Arcadian, Lane	21?	40+14	60?	12 46	42	40	8 32
Arcadian, Pryor,	12+	12T 20A 19T	46A 27T 10A	40T 18A	37T 4A	37T 4A	6T 32
St. Mary, Marvine	25M, 9A	78M	10A 42M 6A	65T 4A	11T 4A	14T 4A	226
Peninsula, Denton	3, 9, 19.7	71, 2	74A 46.8T 4.3	57.2 1.8	32T 4.3	4.9 43	18, 51.8, 21.5

Though we cannot satisfactorily correlate the individual lava flows, we can correlate the group as a whole, none of them very thick, all feldspathic, not ophitic, glomeroporphyritic and probably with irregular streaks of amygdaloid in them. Marvine's XV shows that they occur beneath a heavy bed of coarse grained melaphyre, which corresponds to sheet 20 of Tamarack 5. 1452 to 1834 or to sheet 21, Tamarack 5

1834 to 2011, and that we then have a set of smaller but similar flows (Tamarack 22 and 26) the boundaries of which are hard to determine.

11. Melaphyre glomeroporphyritic ophite, Quincy foot.

Arc. 5, 341 to 350 Amygdaloid -472 Trap (130)
Arc. 6 57 and less -152 T=(100+)

This correlation of 472 and 152 which is reasonably certain seems to imply a dip of 58° (or a fault or a different strike) instead of 50° as taken in the section. Marvine's gives and uses 52°¾ for St. Mary's. The difference in reduction factor is that for 50° it would be .996; for 52°¾, 991; for 58° .974, not over 2% in reducing the thicknesses on the drill holes, but in comparing with horizontal thickness the factors would be .766, .796 and .848 respectively, or very considerable. Thus the distance of the base of this flow above the Albany and Boston conglomerate base may be scaled all the way from 410 to 330, with a presumption that at an angle of 52°¾ it is not far from 370 or in accord with the above figures above the Albany + Boston conglomerate (379)

I take it that this includes the 32-feet melaphyre, 81-feet melaphyre and 11-feet amygdaloid,—"Supposed Pewabic cupriferous bed"—of Marvine's cross-section XV (124) feet thick, the base of which Marvine makes above the Albany and Boston (354) ft.

In the 70 fathom cross-cut of the Pewabic it was (318) feet

This thick glomeroporphyrite has as usual in such flows an accumulation of augite and faint ophitic texture low down, e. g., Arc. 5, 412 and Arc. 6, 131, 145. The base, which is the Old Pewabic amygdaloid, may be marked by a little sediment. There are about four flows between it and the Albany and Boston.

12. Melaphyre, glomeroporphyritic ophite, Old Pewabic and its foot.

Arc. 5, 472-490 Amygdaloid
Arc. 6, 152-168 Amygdaloid, T. -256, 104 or (101)

There is possibly a little sediment at 152 feet. There are occasional larger porphyritic feldspar crystals. Cf. sheet 27 of Tam. 5, and T. 4b 41, and the Franklin dump. There is an epidote vein crossing it at 160-168 carrying quartz and *copper* and probably this is responsible for some discrepancy in description. For instance, while in Marvine's Section XV from the Pewabic Mining Company 1865, we have (29 feet amygdaloid, 69 melaphyre) 98 feet thick, in the Quincy adit we have a belt from 1491 to 1620 (129) feet thick with some 47 feet of amygdaloid and slips and a vein dipping 47° to N. W. above.

In Marvine's St. Mary's section XV we may assign 9, 10, and 12 feet amygdaloid and 90 feet of melaphyre to this belt (121) which agrees with the Quincy rather than this section. Bottom above the base of Conglomerate 15. 278

13. Ophite.

Arc. 5, 256-285 (29)

It is epidotic and fine grained to 261, then ophitic, mottles of 1 to 2 mm. to 278, at the base a fine grained black trap.

In Marvine's XV we may assign 6 feet amygdaloid and 29 melaphyre to this bed (35 feet). According to his text this is just above the "Albany and Boston Amygdaloid," but according to the Atlas it is just be-

low. Marvine says the bed above marks the lower limit of the coarse grained crystalline melaphyres (p. 85).
Cf. T 3 b 41.
Above the base of the Albany and Boston (249)

14. Feldspathic ophite. (70)
Arc. 6, 285-306+
Base above the base of the Albany and Boston say (105) feet
Here the Arcadian section fails a short distance. We may complete it from Marvine. To this bed we may assign
7 feet amygdaloid "Albany and Boston"
31 feet melaphyre
20 feet melaphyre

58

But from Pryor's section there is not less than 120 feet to the epidote on St. Mary's lode, and with the steeper dips than 50° it would be more. The Pewabic cross-cut XV d gives 16 "green Amygdaloid" + 80+8 Albany and Boston + 41=145 for Belts 13 and 14.

15. Feldspathic ophite probably (65)
To this bed we assign 10 Amygdaloid + (17+38) Melaphyre in XV, 8+ 41 in XV d

16 St. Mary's Epidote lode. Indurated epidotized Ash. "Jasper" or sandstone.
By Pryor's section 14 feet (5)
By Denton's section of the Peninsula (Franklin Junior) there is 15.8 amygdaloid, + 3.9 trap + 3.9 indurated sandstone. Probably the same as T. 1, 460. In Marvine's XV (probably overlooked in XVa) described as of brown and green compact matrix with amygdules of calcite, delessite, green earth and quartz often very siliceous with some copper. In XVd included in 23 feet amygdaloid correlated with the "epidote" amygdaloid.
In XVe presumably in a 6-foot amygdaloid "light green and brown with hard conchoidal fracture, very siliceous" below a 72-foot bed of trap. Base above the base of the Albany and Boston about (90)

Hubbard says that this belt is in the Peninsula 110 feet west (67.7) feet above, the Albany and Boston, (29.1) feet thick or (96.8) feet.
In the Quincy mine map it is called the Mesnard epidote and is only 60 feet horizontally from the conglomerate. In the adit it did not appear at all, was perhaps also wiped out by the slide.
Cf. Isle Royale VI 81-91

END OF ASHBED GROUP. BEGINNING OF CENTRAL GROUP.

17. Small ophite ? about (10)
In Marvine's XV, overlooked; in XVa, the amygdaloid melaphyre and covered gap directly beneath the "epidote lode."

18. Small ophite ? all that is left of the greenstone.
Cf. in Marvine's XV the 40 feet of melaphyre just above the Albany and Boston conglomerate.
Thickness about (42)

19. Albany and Boston or Allouez conglomerate, No. 15
By Pryor's section (38)

At the Franklin Junior or Peninsula (Denton and Hubbard) (23.6+ 5.5 fluccan=29.1)
In the Pewabic mine (32)
In the Quincy adits its place is taken by a slide.

The base of this conglomerate is a great reference plane. The strike Pryor found to vary 2° 40′ from that of the Arcadian lode. Some 950 feet horizontally below the Albany and Boston is not shown in the Arcadian section,[1] but may be filled in by the section at the (Peninsula) Franklin Junior mine (Fig. 40) (or one of the Quincy adits which is, however, farther away and quite different), and by the old St. Mary's section given by Marvine.

20. Melaphyre, feldspathic ophite.

Franklin Junior	Amygdaloid	(31) in XV	(40)	
	ophite	(50) in XV	(63)	(81)
		(81)	103	

21. Ophite, feldspathic?

Franklin Junior	Amygdaloid	(13) in XV	(9)	
	ophite	(16) in XV	(31)	(29)
		29	40	

22. Ophite

Amygdaloid	(13) in XV;	(8) "Ragged Amygdaloid" of XVa	
Ophite	(30)	(15+) "dark green speckled with red, hard"	
Altered epidotic seam	(14)		
Ophite	(83)	(at 27 feet from foot 2 to 4 in. calcite vein).	(140)

23. Ophite.

Amygdaloid	(5)	(41)
Ophite?	(36)	

24. Ophite

Amygdaloid	5	
Ophite	46	51

Below the base of the Albany and Boston in the Franklin Junior. 342

25. Houghton conglomerate No. 14
Franklin Junior 5.456-524 (51)
Quincy 958-978? (15)

In the Franklin Junior this was divided into three parts,—above 38.5 feet of porphyry conglomerate, then a foot of sandstone, dip 49.5°, then some 28 feet of basic conglomerate. Whereas in the Quincy adit the bed supposed to correspond has on top 2 feet of clay, perhaps a fluccan, dipping about 57°, then about 18 feet of felsite conglomerate dipping 59° to 60°. This change in four or five miles is worth noting for around Calumet, the Houghton conglomerate is supposed to be entirely absent. Are not slide faults responsible for confusion? Base below the base of the Albany and Boston (Cf. 15) at Franklin Junior (393) or according to Hubbard (389)

[1] But note what is reported from Shields above.

Slide (at 1583) at Quincy? (475)
Marvine's XIV and XVb 400 feet horizontally or (380)

26. Ophite, amygdaloid represented by some of the scoriaceous stuff above?
Trap 60 (60)

27. Ophite
Amygdaloid, brecciated with calcite and epidote (12)
Trap (73) (85)

28. Ophite
Amygdaloid (4)
Amygdaloid melaphyre (9) one bed?
Amygdaloid (13)
Ophite (41) (67)

In the Franklin Junior a steep slide striking northeast and southwest and dipping southeast might involve faulting.

29. Ophite
Amygdaloid (32)
Ophite (58) (90)

30. Ophite
Amygdaloid (32)
Trap (60) (92)

31. Ophite
Brecciated amygdaloid (7)
Trap (30) (37)

Below the base of the Conglomerate 15 (820)

Somewhere near here, depending on the exact dip, Arc. 8, which is about 970 feet horizontally from the Albany and Boston, begins its record.

32. Ophite
Amygdaloid (21)
Trap (5) (26)
(26)

33. Ophite
Amygdaloid (16)
Ophite (5) (21)

34. Basic conglomerate?

Above and below the amygdaloids are so heavy that for some 71 feet amygdaloids are dominant, and this heavy band of amygdaloids is about 186 feet above the conglomerate supposed to be the Calumet. Cf. Tamarack 5, flow 46.

35. Ophite
Amygdaloid with possibly a thin layer of basic conglomerate (20)
Trap (66) (86)

Arc. 8, 68-133
7, 27-50

36. Ophite
Amygdaloid 4
Ophite 48

Coarse altered *cupriferous* seam 2
Ophite 15 (69)

Arc. 8, 133-261?, 128
Arc. 7, 50-210, 160

37. Ophite
Amygdaloid 5
Ophite 42 (47)

Arc. 8, 261-310+1
Arc. 7, 212-222+

38. Conglomerate (No. 13)

Capped by 4 inches of fluccan, brecciated and seamed with calcite from about 14 feet in Franklin Junior, largely of sandstone changing in five feet to a more basic and scoriaceous character, terminating in a six inch seam of sandstone. This resembles the bed in Arc. 8, 290-406. (36)

Under this, at the Franklin Junior were:

33. Porphyrite, feldspathic melaphyre (92)
34. Porphyrite, amygdaloid, with clay cavities[1] (42)
35. Ophite[2] (113 to 123 at Calumet, 103 at the Centennial) seam dipping 56° to the west with seams dipping 45° to east and southeast (103)
36. Ophite (57)
37. Ophite[3] (19)
38. Ophite[4] (138)

113 to 123 at Calumet, 103 at the Centennial.

Thickness from base of Calumet to top of Osceola at the Franklin Junior (451)

Total thickness below Conglomerate 15 (1105)
Hubbard, p. 140, gives (1108)
Below Conglomeratè 14 (719)

Then Ophite (15) + (83) = 89 in the Franklin Junior cross-cut, 135 in the shaft at Calumet

= Arc. 8, 406 to 491 85
= Arc. 7, 319-395 76

Ophite (5) + (59) = (64), (seamed) in the Franklin Junior cross-cut ? at Calumet, 112.7

= 55 or more in the shaft
= Arc. 8, 491-637
= Arc. 7, 395-523

Ophite (4) + (121) = (125)
= Arc. 8, 637+
= Arc. 7, 523+

Ophite (8) + (84) = (92)

To Kearsarge or North 364
Star cg. 12-10 45 Capped by 16 inches of fluccan

409

[1]109 to 99 at Calumet. 115 at the Centennial.
[2]These three next flows appear quite different at Calumet (see notes on Centennial cross-cut)
[3]Calumet amygdaloid near here.
[4]Hanging of Osceola?

According to the above correlations, Holes 7 and 8 reach the bed above the Kearsarge conglomerate,—according to Pryor's section, there is about 227 feet between the base of Hole 7 and the top of the Kearsarge North Star, and the whole belt from the Calumet to the Osceola is represented by the disturbed belt from Arc. 8, 310-406 and Arc. 7, 222-319.

The 970 feet horizontally below the Albany and Boston is equivalent to from (735 at 48° to) (762 at 52½° or) (830 at 59°) and the 1608 feet to the base of the Calumet and Hecla bring it at from (383) to (336) or (278 feet) respectively in Arc. 8.

From the conglomerate Pryor crossed in his run, it is 2470 feet, (Cf. 2581 feet at the Franklin Junior) which will be from 1750 to 1950 or 2100 feet of thickness according to the dip chosen. It is practically the same, allowing for a greater dip, as at the Franklin Junior two miles away (1971).

According to the figures here given it is:

From base of Albany and Boston to base of Calumet and Hecla,	(1108) ft.
From base of Calumet and Hecla to base of Kearsarge,	(842)
Total	1950

Arcadian Holes 8 and 7, though planned to show different strata, appear to show nearly a repetition. Cf.

Arc. 7	222	319	395	520 with
Arc. 8	290	406	491	637
	68	87	104	117

Pryor however thinks the correlation should be Arc. 7.50-212 with Arc. 8.491-637, which is possible as they are both well developed ophites about 150 feet thick. The disturbed belt would then not be the same horizon, but merely similarly disturbed as according to the section Arc. 7.0 should correspond to Arc. 8.420. This would imply a fault of some 300 feet and more, or horizontally 400 feet, as the direction of the holes is nearly at right angles to the strike. I will give the correlation both ways.

They begin in the base (probably of an ophite) a fine grained black trap which may be separated by a little sediment from the next seam.

Ophite.

Arc. 8, 133-145 Amygdaloid -261, 128
Arc. 7, 50-60 -212, 162

Amygdaloid top Arc. 8, 261-272-290? 29
Arc. 7, 212-222+ 10

38. Scoriaceous conglomerate and sandstone, the Calumet conglomerate? much disturbed and probably faulted.

Arc. 8, 290?-406, plainly a sandstone about 358, 116
Arc. 7, 212 -319, (cf. 255?), 97?

39. Ophite, amygdaloid top mixed in belt above, mottles up to 3 mm.

Arc. 8, 406-491, 85
Arc. 7, 319-395, 76 or
Arc. 7, 50

At the Franklin Junior the beds under the "Calumet conglomerate" are reported as a porphyrite which does not appear here, except possibly in the disturbed belt?

40. Ophite, about 10 feet of amygdaloid, mottles up to 4 or 5 mm.
    Arc. 8, 491-637, 146
    Arc. 7, 395-523, 128 or
    Arc. 7, 50-212, 162
    Below base of Calumet and Hecla No. 13. (50+?) (231)
41. Disturbed belt in part sedimentary.
42. Arc. 7, 212-319, 102 (100)
43. At 212 some amygdaloid, to 222 fine grained green epidotic, then some scoriaceous amygdaloid, dense fragments of amygdaloid, and calcite, red shale? a sediment or slip to 288. 288-319 sludgy. This may include the horizon of the Calumet Amygdaloid.
    Base below the Calumet and Hecla? (333)
44. Ophite (top disturbed, in sludge and possibly the horizon of the Osceola amygdaloid.
    Arc. 7, 319-395, 76 (74)
    at 319, 334, 351 feet
    Mottles 1-2, 2, 2½ mm.

407

45. Ophite. (Probably the fourth above the Kearsarge conglomerate top, probably the *Osceola amygdaloid*?)
    Amygdaloid Arc. 7, 394-401, 7 feet top to
    Trap 523 (125)
    Well-marked; at 437, 452, 463, 489, 499, 502, 512 mm.
    Mottles 2, 3, 5, 3, 3, 1 to 2, 1 to 2 mm.
    Cf. (83) or (138) feet of Franklin Junior
    Base below Calumet and Hecla 50+? (532)
    Above the base of the Kearsarge conglomerate by scaling > (310)

    Cf. with 863 feet at the Franklin Junior (842)
46. Ophite? 64?
    Amygdaloid Arc. 7, 523-530
    Trap -544+ 21+ (64) or (83) feet at Franklin Junior?
    Base below the Calumet and Hecla (596)
    The three beds above are some of the large ophite flows which occur in the Franklin Junior cross-cut just above the Kearsarge and below the supposed Osceola?

47 &
48. Two ophites not pierced in this cross section.
    Cf. the 92 feet of ophite flow just above the Kearsarge conglomerate at the Franklin mine, and the 125 feet just above (125)
    (92)

    (813)

    Above correlations are such as would be suggested by Pryor.
49. Kearsarge conglomerate say to balance (29)
    At the Franklin Junior it is (36) (842)
    Upon comparison with the Calumet and Hecla section it is clear that between this and the Arcadian-Franklin Junior sections a thinning of 100 feet or so has taken place. This does not appear to be due mainly to the thinning of the various beds, but rather to the elision of some of them by slide faults confined mainly to the upper part of the section, which may be represented by the disturbed belts in Holes 7 and 8.

The first 400 feet above the Kearsarge conglomerate, composed in the Franklin Junior of four heavy ophite flows, or even the first 500 do not show much disturbance there or at Calumet, but the first 300 feet under the Calumet conglomerate show much disturbance which evidently corresponds to the disturbed belt (or, if they are not the same, belts) of Arc. 7 and 8. This disturbed belt at Calumet centers about and above the Calumet amygdaloid, the top of a large ophite flow just above the Osceola. I have correlated accordingly.

The following beds are taken from Pryor's section, and were compiled by him from records at Calumet.

49. Kearsarge conglomerate .(46) feet dip on Pryor's profile 59°¼
50. Trap (58½) feet
51. Amygdaloid (12) and Trap (124), (136) feet
52. Amygdaloid (31) and Trap (31), (62)
53. Amygdaloid (15) and Trap (33), (48)

In Arc. 1[1] there is a fissured melaphyre at Arc. 1, .39 feet

54. Amygdaloid (25) and Trap (78), (103) feet. Total from base of Kearsarge conglomerate (407) feet. The amygdaloid under this, Pryor takes to be the first belt encountered in No. 1 hole 53-57 feet. This was put down at an angle of 45°, i. e., so nearly at right angles to the dip which is probably about 58° that the reduction factor (= sin 103°+) is .974.

55. Amygdaloid (4) and Trap (56) feet, Pryor. I make the lower contact at Arc. 1, 109 feet. The belt is slightly glomeroporphyritic at the top, ophitic at Arc. 1, 79 feet.

56. Amygdaloid (7) and Trap (19) Epidote seam (3) Trap (4). 30 feet of a small flow, epidotic from Arc. 1, 135 to 138 and then amygdaloid again.

Amygdaloid (23) and Trap (26), in all Pryor (82)

Very feldspathic and but faintly ophitic, coarsest near 167.

Cf. C. & H. C 56 to 84 (28+) which is also feldspathic ophitic.

Total from top of hole 191

Total from base of Kearsarge conglomerate (549)

57. Amygdaloid melaphyre Arc. 1, 191 to 211 (20)
seamed at an angle of 26° to the hole

58. Amygdaloidal melaphyre or two or three flows Arc. 1, 211 to 224 (13)
A hard gray amygdaloid, seamed at 219 and 222 feet.

59. Amygdaloidal melaphyre. Amygdaloidal 224 to 239, to Arc. 1, 240 (16)

60. Amygdaloidal melaphyre Arc. 1, 240 to Arc. 1, 255 (15)
Pryor Amygdaloid (6) with Trap (10)

61. Amygdaloidal melaphyre, Arc. 1, 255 to 262 (7)
Cf. Calumet and Hecla C. 84 to 135 (51) feet, which has three or more flows.

The above five flows 57 to 61 are not clearly defined and may be more or less gushes of one, together they make a broad amygdaloidal belt, the thickness of which is about (71) feet, and the base below the top of Hole 1 (262) and so below the base of the Kearsarge conglomerate (605) feet.

62. Ophite. Arc. 1, 262 to 385. 123 feet or reducing. (121)
Cf. C. and H. C 135 to 226 (91) feet; and Central mine, (Figure 33, Belt 53, d. 2.259-333 (74).

This begins with 9 feet of marked amygdaloid and at Arc. 1, 278 to 290 is another marked amygdaloid, which may, however, be a flowage seam.

[1] In Figure 42, drill hole 1 is shown, just N. W. of drill hole 2, but its number has accidentally been omitted by the draftsman.

At 1, 299 feet it is for 2 feet epidotic to 302 feet, and at 312 to 317 feet and 320 to 324 feet and at 347 feet about 8 feet and at 304 to 311 it is amygdaloid in spots, but the coarsening grain shows it is all one flow and that these are merely flowage or alteration streaks. At 340 feet the mottles are about 10 mm. across? This is taken to be the hanging trap of the Kearsarge amygdaloid and its base is then below the conglomerate[1] (726) feet.

63. Kearsarge Trap,—an ophite characterized by the presence of porphyritic, sharp, flattened crystals or groups of crystals of labradorite up to 20 mm. long especially in its upper part which is otherwise either amygdaloid with red amygdules and white centers or a dense, fine grained, hard trap, while the bottom is plainly ophitic, though often dense, hard, and aphanitic for an unusually large distance from the bottom.

In Arc. 1, 385 feet to the end at 428 feet which is like Arc. 2, 78 from which to the base at Arc. 2, 143 feet is 65 feet or in all (109) feet

Arc. 2, 42 to 50 is a laumontite amygdaloid which then changes to a yellow-green, hard white trap which at 2, 81 is rather feldspathic, independent of the coarse labradorite crystals, but at 94 to 96 shows the 3 to 4 mm. ophitic mottling plainly.

Hole 2 shows there must be not less than (143-42) 101 of the Kearsarge footwall trap and its amygdaloidal top shows that there is not very much more. If the dip is steeper than 58 to 59° there will be more. Cf. C. & H. A. 54-198 (144) and C. & H. C. 226-281+ (55+)

Cf. Central mine 2, 333 to 408 (75) which is somewhat different in appearance.

At the Wolverine mine the foot trap is 187 feet, it is said.

64. Wolverine sandstone. Marvine's slaty sandstone No. 9, Arc. 2, 143 to 178 (35)

The first 21 feet are red, sandy shale dipping (8:15 or) 72° apparently. Dip on profile 59°. Its top is by addition (846) or by scaling (831) feet below the Kearsarge conglomerate and its base below the base of that (866)

Marvine makes No. 9, the "slaty sandstone" (720) feet below the Kearsarge at the Shelden and Columbia, but he also recognizes 10 and 11 as different beds. From 12 to 10 and 11 is (655) + (196) feet. The Wolverine sandstone is about 21 feet thick, and may correspond only to the upper 21 feet of this.

65. Ophite. Arc. 2, 178 to 262=84 or (82)

Unless the scoriaceous base of the Wolverine sandstone be such in part, there is no marked amygdaloid top to this. At Arc. 2, 187 it has a 2 mm. ophite mottling. At 220 this is about 4 mm. At Arc. 2, 262 it becomes fine grained, though there is no clear contact.

This is Pryor's amygdaloid from 228-235 and trap to 260, "much altered from 243 to 255."

Below the base of the Wolverine sandstone (82) feet

C. & H. A. 198-270 (72) top lost? Wolverine 319-406 (56)

Central mine 2, 412-442 (30) and 2, 442-498+ (56+) which agrees better.

66. Melaphyre.

Feldspathic verging on glomeroporphyritic.

Arc. 2, 262 to 315 (51)

[1] Scaling from Pryor's cross-section from the top of the Kearsarge conglomerate, with an assumed dip angle of 59°.

Cf. C. & H. A. 270 to 361 (91); Central mine 442 to 498+ (56+) which really agrees better with the bed above; also Central mine) 0 to 27.

This includes Pryor's amygdaloid 260-273, "good looking, chocolate medium,—a little epidote in places,—315 trap grayish, medium, in some spots altered."

67. Scoriaceous conglomerate? at Arc. 2, 315 to 320? (5)?

Cf. Central mine 1, 27 and 43 passim also.

68. Melaphyre, a feldspathic bed with a scoriaceous amygdaloid top passing into conglomerate (Arc. 2, 315 to 322) 464.

At 377 and other points coarse doleritic spots, labradorite 8 mm., and red, micaceous, altered olivine show well, also dark chloritic amygdules. Toward the bottom it is faintly ophitic. Finer? at Arc. 2, 436 with a green amygdaloid streak at 452, but apparently coarse and all the same flow to the end of Hole 2 at 464. This is probably Dr. Hubbard's "*inclusion*" bed and the spots and streaks are the inclusions.

This includes Pryor's amygdaloid 2, 315-329, part chocolate, part dark, pretty well sprinkled with calcite, some laumontite, 315-320 looks like amygdaloid conglomerate,—464. Trap medium altered, in spots and seams, sometimes a little bunch of epidote, at 447-450 a little bunch of *copper* and epidote. End of trap, at bottom finer than at top. I put the mottling 10 mm. at 440 with some questions. This coarseness of grain would indicate about 150 feet more. This would correspond at a dip of 59.5° with Arc. 19, 155 feet instead of 120, i. e., 35 feet difference, and would make the bed 267 feet thick instead of 217. It is epidotic at 129 and the contact may be a few feet higher up. However, we correlate Arc. 2, 315 to 464+ and Arc. 19, 43 to (120) or 139 (217)

Pryor makes No. 19, 0-43 overburden, then to 120 trap. At 63 to 67 calcite fissure gray, becoming darker toward the end. The Pryor section makes the dip of Hole 19 52°?, but that appears to be too flat by correlations. C. & H. A. 361-406 is a group of amygdaloid and trap belts with sediment and scoria. Cf. Arc. 1, 315 to 322. If we can thus group them then to this belt will correspond C. & H. A. 361-656 (295) which like this is feldspathic only faintly ophitic, if at all, but doleritic. Central mine Hole 1 shows also a series of ophites with marked scoriaceous amygdaloids at this horizon.

69. Scoriaceous conglomerate? Arc. 19, 139-139 1

Below the base of the Wolverine sandstone about (355)

Cf. C. & H. A. 656; Franklin Junior d. 3, 535.

70. Melaphyre.

From Arc. 19, 120 to 135 it is markedly amygdaloidal. One foot epidotic at 153. There are signs of scoriaceous conglomerates along here possibly misplaced.

Arc. 19, 139 to 153, 33 or (32)

71. Ophite with scoriaceous amygdaloid and basic sand or sludge.

Arc. 19, 153 to 251, 98 or (95)

The above two may be one belt. Cf. C. & H. A. (656 to 752.6+)

Pryor comments "42 feet amygdaloid, reddish, rather rotten with calcite, prehnite and sludge."

72. Ophite.

It is poorly amygdaloid to 288 feet, then ophitic mottles which are coarsest,—6 mm. across at about 345 feet, at 350 feet 5 mm., plainly finer at 376 feet.

Arc. 19, 251 to 270 amygdaloid (with scoriaceous conglomerate?) to 398 trap 147 or (143+)

Below the base of the Wolverine sandstone (625)

73. Fault zone possibly bed of sediment, a mixture of sediment, clay fluccan and fine grained trap to be divided in uncertain amounts between the belts above and below. Pryor also thinks that the core ran through a seam here.

Arc. 19, 398-424 (25)

Below base of Wolverine sandstone (650)

74. Feldspathic ophite, mottling not well marked.

The base has long amygdules and a *little copper*, coarse, with doleritic spots, and prehnitic amygdules; at 475 doleritic spots of very coarse feldspar.

Cf. Franklin Junior d 1. 126-243 (117)

Arc. 19, 424 to 620 (196 or) (190)

Below the base of Wolverine sandstone about (840)

75. Feldspathic ophite.

Coarse amygdaloid with large amygdules. At 705 to 708 4 to 5 mm; at 650 and 719 3 mm.

Arc. 620 to 745, 125 i. e., (122)

Below the Wolverine sandstone (962)

Hole 19 ends at 767½ feet.

We pass here to Arc. Hole 20 of which this is the top bed.

76. Sandstone (No number by Marvine, say 8½.) Cf. "Old Colony" sandstone.

This has on top red shale, then about two feet of *copper bearing* epidotized sandstone, and clasolitic veins of this epidotic sandstone extend down into the red and white amygdaloid beneath. In the Arcadian 20 at 54 feet there is a seam of epidote and indurated sediment underlain with amygdaloid largely ground to sludge, which appears to be the same. The dip using this correlation would be 58.5°, instead of the flatter dip used in the section. So I think we may safely assume a dip of about 59° through Hole 19 as well as for the holes each side.

Arc. 19, 745 to 749½ (4)

20. 54+

Below the Wolverine sandstone (968)

This may be the "Old Colony" sandstone which is 980 feet below the Wolverine.

The 122-foot bed in Arc. 19, just above, is too thick to be anything but the top bed of Arc. 20, and beneath it in each case is similar epidotic and indurated sediment, though Arc. 20 seems to be near a fault, and the contact is not clear.

77. Ophite, feldspathic, often doleritic.

Pryor says that this amygdaloid is light gray to chocolate, good average, with some epidote, the top part of the trap also slightly amygdaloid, the bottom brown.

Arc. 20, 54 to 134 80 or (78)

The samples were perhaps not in good order,—indurated sediment and sludge were scattered through.

78. Ophite, feldspathic, doleritic

Dip from amygdaloid contacts seen in the drill core 59° to 64°. From

the cross-section it would only be some 49°, and presumably in projecting on the cross-section the strike was taken too much north; the distance along the strike is considerable relative to that across it.

Arc? 20, 134 to 200, 76 (54)
Arc. 21 to 95, 74

From the base of the Wolverine sandstone (1100)

Above the hanging of the Arcadian lode about (1350)

The feldspathic doleritic ophites of the top of Arc. 20 and 21 and bottom of Arc. 19 are hardly ophites at all,—may be a recognizable group, and if so, are recognizable in Franklin Junior Hole 1, and Hole 2.

79. Ophite
A small flow somewhat amygdaloid throughout. Mottles not over 2 mm.
Arc. 21, 95-124? (29) or (28)
Arc. 20, 200-239 (39)

80. Ophite, feldspathic, with doleritic inclusions in Arc. 20.
The amygdaloid is well marked and has COPPER.
Arc. 21, 124-140 am.,-247 trap, 123 or (120)
Arc. 20, 239-250 am.,-291 trap+
The dip by correlation is about 59°, according to the amygdaloid contacts 59°, 64°, 75°.

Above the hanging of the Arcadian lode about (1202)

81. Brecciated amygdaloid and feldspathic ophite.
Dip between 59° and 75° according to amygdaloid contacts which average along here 65° if the holes are at 45°
Arc. 21, 247-332½, 85½ (83)

82. Brecciated amygdaloidal melaphyre
Arc. 21, 332½-348 15½ (15)

83. Scoriaceous amygdaloid and doleritic ophite
Arc. 21, 348-430 80 or (78)

From base of Wolverine sandstone (1424+)

84. Scoriaceous amygdaloid and feldspathic melaphyre
Arc. 21, 430-471 am.,-550 trap, 120 (116)

From the base of Wolverine sandstone (1540+)

85. Melaphyre.
This is not ophitic, compact and rather fine grained.
Arc. 21, 550-571 am.,-663 trap, 113 or (110)

From the base of the Wolverine sandstone (1650)
Above the Arcadian hanging wall (800)

86. Ophite, dark, yet but faintly ophitic
Arc. 21, 663-667 marked red amygdaloid with some copper
trap 756+ (128)

Arc. Hole 22 begins in a massive trap which is not very remarkably ophitic yet dark and chloritic, seamed, with brown specks of altered olivine. It begins somewhat amygdaloidal at the top 17 feet and appears to have 2 mm. mottles at 40. At 91 feet may be the bottom. Assuming 30 feet not represented this would make the bed (104) feet thick, plus some allowance for amygdaloid. Scaling from Pryor's section makes it (120); steeper dip would give greater thicknesses. The

last bed in Arc. Hole 4, bored horizontally northwesterly[1] from Arc. 4, 362 to Arc. 4, 453 is fissured, faintly ophitic and doleritic and presumably the same bed.

N. B. From here on the thicknesses are derived from horizontal measurements by multiplying by sin 57⅔=.845 while previously they have been obtained from thicknesses along drill holes at an angle of 45° by multiplying by sin 76°=(180°-59°-45°)=.970 from No. 9 down.

Base from the base of the Wolverine sandstone about	(1778)
Above the Arcadian horizontally 794 feet, or	(672)

87. Ophite

Arc. 4. 348-362 is an amygdaloid the samples of which were ground up, the "vein" reported to be about 9 feet thick, there was a laumontite vein above it at 371 to 374 feet.

Arc. 22, 88-95 is called amygdaloid chocolate at top, epidotic at bottom.

At Arc. 22, 160 there is a laumontite seam and it seems finer grained above it, possibly a slip, also at 4, 371 to 374.

The underlying trap is a dark and well-marked ophite, represented by

Arc. 4, 348 to 250, in all 112 or by Pryor 141 feet across, which reducing by .845, gives a thickness of (95) or — (119)

Arc. 22, 91-210, 119 or — (115)

88. Melaphyre.

Arc. 4, 250-243 was a grey-green amygdaloid.

This is feldspathic only, coarsely amygdaloid, not ophitic; the amygdaloid is reddish decayed, amygdaloid faint .

Not a marked flow.

Arc. 4, 250 or 221-188, 62 or 33 feet across which reducing by .845 gives (52) or (28)

Arc. 22, 210-216 amygdaloid -250 trap. — (40)

89. Amygdaloidal ophite.

This is more or less amygdaloid throughout and it may be made of smaller flows, e. g., 4, 173 to 184 amygdaloid with prehnite and copper and 4, 149-158.

Arc. 4, 188 to 121, 67 feet across which reduces to	(57)
Arc. 22, 250-254 amygdaloid grayish green -288	(38)
From the base of the Wolverine sandstone say	(1982)
Above the Arcadian hanging	(468)

90. Arc. 4, 121 to 32, 91 feet across which reduces to	(77)
Arc. 22, 288-316 Am-3700 or so	(82)
Above the Arcadian hanging	(391)

91. Amygdaloid melaphyre

382 feet above the top of the Arcadian lode, 365 by scaling from Pryor's plan to Arc. 22, 370.

Arc. 22, 370-398 is a grayish, coarse amygdaloid.

Arc. 4, 32-11 is a greenish, much altered amygdaloid with considerable laumontite, evidently the top of the trap belt at the end of the cross-cut west from the 8th level, which was 432 feet long, i. e., ends (356) feet

[1] So that the uppermost beds are those struck at the end of the hole. Hole 4 is shown in Figure 42, but its number is omitted.

above the foot of the Arcadian hanging. Comparing the thickness of belts in the horizontal hole and the one at 45° (No. 22) we have $\frac{28}{31}$, $\frac{21}{32}$, $\frac{57}{88}$, $\frac{23 \text{ or } 33}{40}$, $\frac{112 \text{ or } 141}{119}$, values ranging from .90 to .57, averaging .74 or from the total distance about .81 whence by the formula:

(Cot. dip + 1) x cos 45°=ratio length along horizontal hole

Cot dip + 1 = length along hole at 45°

$.\frac{1}{707} \cdot .\frac{1}{571}$ = 1.751 .˙. dip=53° (or from .74 62°½). Scaling from Arc. 22, 370 and Arc. 432 to the Arcadian lode we get 52°⅓, while Pryor shows the actual dip of the Arcadian No. 2 shaft to be 56°. Hubbard gives the dip of the Arcadian 56.5°.

The correlation of Arc. 22 at 370 and Arc. 4 at 32 feet gives 53°¼. The coefficient of reduction for the thickness of a belt at an angle of 45° is sin 82°=.990 about 1%.

92. According to Marvine (Plate XIX, Section 1, Atlas to Vol. 1) down at least to (300), perhaps down to (180) above the Isle Royale Arcadian lode[1] is a heavy bed of trap, the faintly amygdaloidal and somewhat glomeroporphyritic upper part of which is found in Arc. 4, 1-32? It is not clear that there is any contact here or near the bottom of Hole 22 from the samples, though Pryor thought so. It may be merely a pseudamygdaloid or altered belt, so that the thickness given may perhaps need to be added to the previous belt.

Thickness perhaps	(211)
Foot above the Arcadian	(180)

93. Shelden-Grand Portage-Columbian amygdaloid and underlying trap. It is a rather coarse amygdaloid? (70)

94. Small amygdaloid and melaphyre (Marvine 11. k) ? (39)

95. " " " " " " (44)

The Isle Royale Hole 3 does not seem to show these beds. Are they faulted out?

96. The immediate hanging of the Arcadian lode is exposed at the mine and is a coarse feldspathic amygdaloid (27)

Hanging of Arcadian lode below Wolverine sandstone (2450) feet

The Arcadian lode dips 56.5° and strikes N. 37° 49′ W.

Between the Arcadian lode and the beginning of drill hole 3, at the end of a cross-cut at 104 feet into the foot, the section is completed by exposures on the surface, practically continuous, which show that the interval is occupied by a melaphyre full of bombs or inclusions as described by Hubbard, pages 77, 78 and 132. Compare also Arc. 21, 144 to 177. Such inclusions in drill holes often make difficulty in determining the exact bounds of different flows.

97. Inclusion bed, melaphyre.

To Arc. 3, 17, 140 feet horizontally or (118)

Below the Wolverine sandstone 2568

98. Amygdaloidal melaphyre.

Greenish amygdaloid, coarsely amygdaloidal throughout.

Arc. 3, 17 to 39, 22 feet horizontally or (19)

[1] See Belts 3 and 1 of the Isle Royale, § 14, just below.

99. Ophite.

Coarsely amygdaloidal, chocolate and not numerous amygdules, but at the foot of the amygdaloid (48′-50′) very epidotic.

Arc. 3, 39 to 143, 104 feet horizontally or	(88)
Amygdaloid melaphyre	
Arc. 3, 143-160, 17 feet horizontally or	(14)
Below the Wolverine sandstone	(2689)

100. Melaphyre.

With epidotic brecciated amygdaloid, with chlorite and epidote well-marked, and a fine grained, dark, compact trap below. This is crossed by a vertical seam near 180 feet.

Arc. 3, 160-196, 36 feet horizontally or (30)

101. Ophite.

The amygdaloid contains a trace of *copper*, the trap shows well-marked mottling up to 4 mm! at 225 a seam makes an angle of 47° with the drill hole.

Arc. 3, 196 to 235, 39 feet horizontally or (33)

102. Ophite.

Green and white, epidotic amygdaloid fading off to Arc. 3, 250. Then ophitic; at 294 ¾ mm. at 304 6 mm.

Arc. 2, 233-320, 87 feet horizontally or (73)

103. Ophite.

Amygdaloidal, (trap 333-340)

At 339 the dip appears to be 56° and at 390 seams of laumontite appear to dip 58°.

Arc. 3, 320-394, 74 feet horizontally or (62)

104. Ophite.

(394-397 amygdaloid, greenish, epidotized,) really includes the next belt which I separated because Pryor did in Arc. 3; in Arc. 9 we both keep them together.

The thickness of this hole in horizontal cross-cut and drill hole indicates 74° dip or so, but the fault may have something to do with it.

Arc. 3, 394-491 57 feet horizontally or	(48)
Arc. 9, 14	
Below the base of the Wolverine sandstone	(2935)

105. Ophite.

451-453 faint green and white amygdaloid; I think this is a bomb, and this flow and the one above the same, because I make the mottling at 472, 5 mm. and 491, 3 mm. and again in Hole 9 Pryor and I agree in making one big belt above the conglomerate.

Arc. 3, 451-508, 57 feet or	49
Or adding this and the belt above as one flow	(97)
Arc. 9, 14 (beginning of rock) to 116	(102)

Total from the base of the Wolverine sandstone, Marvine's No. 9, to the foot of the ophite which is the hanging wall, (with a slide) of No.

8, conglomerate	2989
Below the top of the Arcadian lode	549
From foot to foot Hubbard makes	552

SLIDE; clay fluccan, apparently to be counted mainly with the overlying trap of which it is a disintegrated portion.

Arc. 3, 508 to 515, 8 feet horizontally, or 7 feet

END OF CENTRAL, BEGINNING OF BOHEMIAN RANGE GROUP.

106. Porphyry conglomerate. Winona conglomerate. Marvine's No. 8, the first conglomerate with well-marked felsitic pebbles that we have met in descending the section, since the Kearsarge. This is a regular conglomerate with rounded acid pebbles, also much epidote, calcite and basic material. The dip is apparently 63° to 65° in Arc. 3 and in Arc. 9, 52° 10′, ave. about 58°.

The frequency of conglomerates below is marked here and elsewhere.

Arc. 3, 510 to 548 anyway and perhaps to the end of the hole, 32 feet horizontally, or (27)

This also appears in Arc. 9, 480 feet southeast of the Douglas shaft, from Arc. d 9. 116 to between Arc. 9. 133 and 140 feet or (17) to (24) feet thick and without the clay cap.

The distance horizontally from the top of Arcadian to the base of the conglomerate in the cross-cut is 120+548=668

The distance horizontally from the top of Arcadian in Arc. 9 may be computed as 480+135=665+ and the thickness accordingly below the top of the Arcadian (565)

Or below the base of the Wolverine sandstone (3015)

In this computation of the distance between conglomerates (8) and (9) I do not think that the error in dips is likely to be over 3° and the error in thickness from that cause over a very few feet, but there are uncertainties in correlation of certain of the holes which may amount to 50 feet perhaps.

107. Ophite, doleritic.

At 189 feet laumontitic fissures, and coarse doleritic seams at 212, 228, 244 feet.

Reduction factor used hereafter sin 45°+56.5°=sin 78.5°=.98

Arc. 9, 133 to 266, 133 or (130)

108. Melaphyre, amygdaloid, epidotic, and clasolite, then coarse feldspathic and chloritic and epidotic at base.

Arc. 9, 266-293, 27 or (26)

109. Melaphyre, amygdaloidal, gray-green and epidotic.

Arc 9, 293-310, 17 (17)

110. Ophite marked.

This ophite shows the mottling fine and clear down to 1 mm. and this type is absent between Conglomerates 9 and 8 where the feldspathic ophites do not show the mottling plainly and indeed at all only when coarse. The top is brecciated and perhaps a basic conglomerate

Arc. 9, 310-338, 28 (27)

Below the base of the Conglomerate 8 (200)

(Cf. the bed at 267 feet below)

111. Ophite, amygdaloid 335 to 352; ½ mm. mottling at 354. This of the same type as the one above and should be characteristic.

Arc. 9, 338-365, 27 or (26)

112. Seam of sediment, basic sandstone or shale at Arc. 9, 365

Below the base of Conglomerate 8 (227)

Cf. Hubbard p. 134

113. Melaphyre, mainly amygdaloid to 376
Arc. 9, 365-383, 18 (18)
Ophite, fine grained
Arc. 9, 383-395+, 12+ (12)+

Below the base of Conglomerate 8 (257+)

The top of Hole 10 is according to Pryor's section 239 feet below Conglomerate 8. It is said to be 939 feet east of Douglass shaft. The same section makes the distance between drill holes 9 and 10 some 450 feet.

It begins in fine grained, somewhat amygdaloid trap and soon shows some 3 feet of fine grained, yellow, epidotic sandstone from the dip of which on the drill cores we might infer a dip of (45°+22° 50′) 68° or by other observations 61 to 62°, so that there might be a considerable gap between Holes 9 and 10.

114. Epidotic sandstone. The fine grained character and position of this bed is much like that of Conglomerate 7. See Hubbard's remarks in Vol. VI, p. 108 of Pt. II. Cf. also 112.
Apparent dip 61° to 62°
Arc. 10, 40-43, or more

Below the base of Conglomerate 8 (267)-

115. Amygdaloidal melaphyre, exact position of contact uncertain.
Arc. 10, 43? to 53? (10)

Below the base of Conglomerate 8 (277)

116. Amygdaloidal melaphyre, fine grained, with a glomeroporphyritic base.
Arc. 10, 43? to 68, (25) (25)

Below the base of Conglomerate 8 (302)

117. Melaphyre, epidotic amygdaloid for 10 feet,
Arc. 10, 68-141, 73 (71)
Arc. 12, 15-33

Epidotic seam (amygdaloid or sediment?) at Arc. 10. 102-105 and also at Arc. 10, 121 an epidotic sandstone with a little coarse amygdaloid associated. The trap is fine and glomeroporphyritic and there are possibly two or three beds combined here.

118. Melaphyre, coarse feldspathic.
Arc. 10, 141-156 amygdaloid -182 trap, 41 (40)

Below the base of Conglomerate 8 (403)

119. Amygdaloidal melaphyre, amygdaloid about half way, trap rather dark, medium grained in Arc. 12 above 75 coarse feldspathic.
Arc. 10, 182-195 amygdaloid -209 trap, 27 (26)
Arc. 12, 75- 103, 28
Arc. 13, 46- 62, 16

120. Amygdaloidal melaphyre. The trap rather glomeroporphyritic, fine grained.
Arc. 75-82 clasolite amygdaloid
Arc. 10, 209-237?, 28 (27)
Arc. 12, 103-132, 29
Arc. 13, 62-108, 46

Pryor classed all the rest of Hole 10 from 212 down as amygdaloid, but probably it is made up of a series of small flows as indicated, match-

ing the series of flows in the tops of Holes 11 to 13,—the matching of individual flows being very uncertain.

121. Amygdaloidal melaphyre, with a 2-foot epidotic seam
Arc. 10, 237?-262, 25? (25?)
Arc. 11, 19?-42 , 23?+
Arc. 12, 132 -160, 28?
Arc. 13, 108 -120, 12

122. Amygdaloidal melaphyre, cut by a clay seam at Arc. 10, 268 feet.
Epidote and *copper* at Arc. 10, 291 to 297 and from 303 to 313 coarsely amygdaloid, and then doleritic.

Arc. 13, 62-126 64,	Coarse amygdaloid but plainly ophitic
Arc. 10, 262-287 am.-324? 62	at 13, 110-115 epidote and quartz amygdaloid (61)
Arc. 12, 33-75 or 90, 41 or 56	Amygdaloid at 12, 41 (56)
Arc. 11, 42- 102, 60	This occurs also with a coarse amygdaloid above, and doleritic below, but I also note occasional large feldspar phenocrystals; *copper* at 108-112 just below (59)

Below the base of Conglomerate 8 (452)

123. Feldspathic melaphyres, much disturbed and with more or less copper; in Arc. 11 coarse and somewhat epidotic to 154; then faintly ophitic and contact at 178 with epidotic amygdaloid; then to 231 numerous calcite seams about at right angles to core, and at 231 a faint amygdaloid.

In Arc. 12, to 82 there is 7 feet of clasolite amygdaloid; then coarsely amygdaloid, between 92 and 103 more plainly so but no plain contacts, fine grained, however, to 117, then redder, and at 132 two feet of epidote, and it remains irregularly amygdaloidal with more copper at 163-165,—possibly another contact. Below this it is coarser and at 206 is doleritic, and faintly ophitic. In Arc. 13, it is coarsely amygdaloid from 140 to 145, fine amygdaloid to 150, then coarser, doleritic at 168, and at 195-8 epidotic, then feldspathic coarsely amygdaloid to 236, then yellow and epidotic again, then massive faintly ophitic (3 mm.) with much feldspar and olivine at 250; near the contact at 262 are laumontite veins.
Arc. 10, -324+
Arc. 11, 108-250, 142
Arc. 12, 75-216, 141 (138)
Arc. 13, 125-265, 140
Possibly the limits of this flow in 12 should be at 92 and 232.

124. Feldspathic melaphyre, in Arc. 11, decayed and seamed. In Arc..12, there is well-marked amygdaloid 216-222 and 232-237; below faintly ophitic.
Arc. 11, 250-302+? (52?)
Arc. 12, 216 or 232-280? (64?) or (48?) cut by vertical fissures with calcite and *copper* (63)
Arc. 13, 265-313, (48)

125. Feldspathic melaphyre, with occasional epidote streaks and a fine grained, black and white amygdaloid at the bottom in Arc. 12.
In Arc. 13, coarse amygdaloid with *copper* and calcite vein and fissure about 332-337
Arc. 12, 280-342, 62 (61)
Arc. 13, 313-349+

Below the base of Conglomerate 8 (804)

126. Porphyry conglomerate, with pebbles of all kinds and apparently if the dip of the hole is 45°, a dip of 59° to 62°. There is much matrix. I take this as conglomerate (6) which Marvine's makes (736) feet below No. 8 on the Isle Royale Consolidated property, Hubbard (722). I think that this rather than the one below is the one which outcrops on Section 20, as Hubbard says not over 350 paces (1000 feet) horizontally from No. 8. Omitted by Pryor.

Arc. 12, 342-353, 11 (11)

Below the base of Conglomerate 8 (815)

This would be horizontally 975 feet.

This will be less if the dip is less than 56.5°; more if it is greater.

127. Amygdaloidal melaphyre. Amygdaloid begins well-marked with small amygdules, then at 364 a clay seam. The samples remain amygdaloid and full of fissures to the end of Arc. 12 with brecciated or scoriaceous conglomerate which as Hubbard remarks (p. 134) are characteristic below No. 6 conglomerate.

Arc. 12, 353-408+, 55+ (54)

Hole 14 is planned just to lap this on a 56.5° dip.

It does not begin in the same kind of rock but in a fairly compact rock with a streak of epidote and COPPER at Arc. 14, 32.

128. Melaphyre. Feldspathic, compact with long cores, black, faintly ophitic and without amygdaloidal contact on the conglomerate.

Arc. 14, 40-70, 30 (29)

129. Porphyry conglomerate, various kinds of pebbles, with an epidote and calcite cement. This may be conglomerate (5), which Marvine makes 292 feet below No. 6, but might conceivably be the one above repeated by faulting.

Arc. 14, 70-80 (10)

Below the base of Conglomerate 8 by scaling from Pryor's section (1010)

Below the base of Conglomerate 6 by scaling (160)

But there was an error in platting the position of Conglomerate 6.

We shall take it as below Conglomerate 6 (140)

And below Conglomerate 8 (955)

But there is an uncertainty of some 50 feet independent of what may be produced by faulting.

Cf. Isle Royale bed 31, with which it closely agrees.

130. Amygdaloidal melaphyre, dark with small white amygdules.

Arc. 14, 80-97 (17)

131. Amygdaloidal melaphyre, dark with small white amygdules, with some laumontite, sometimes chocolate, in spots epidote.

Arc. 14, 97-130? 33 (32)

132. Ophite. From 150-170 with fine grained mottling.

Arc. 11, 130-140 am-179, 49 (48)

133. Melaphyre, amygdaloid and pseudamygdaloid, ophite at 306 (4-5 mm.) perhaps more than one flow.

Arc. 14, 179-323, 144 (141)

134. Basic (Amygdaloidal or Scoriaceous) conglomerate in Hole 14 more scoriaceous; in Hole 15 more plainly a basic conglomerate.

Arc. 14, 323-340?	(17)
Arc. 15, 91-101	(9)
Below Conglomerate 5	(255)
" " 6	(395) ft.
" " 8	(1210)

The correlation of these two beds implies either a dip of only 51°-52°, or faulting amounting to not over 35 feet or (and in view of the strikes on Section 29 this seems quite possible,) a veering in the strike reducing the distance between the holes at right angles thereto.

135. Ophite, scoriaceous on top with a very well marked decrease of the mottling below, at:

	125,	132,	141,	142,	148,	161,	168,	171,	186,	191,	211 feet, there are
Mottles	2,	3,	4,	3-4,	4-5,	2-3,	4-5,	5,	3,	2-1,	⅓ mm.

There is a curious band just below.

Arc. 14, 340-363 scoriaceous -363+

Arc. 15, 101-112 Amygdaloid -212 (109)

136. Scoriaceous amygdaloid; scoriaceous, brecciated on top, with a seam of epidote and *copper* at the base, possibly belonging to the ophite below.

Arc. 15, 212-248, 36 (35)

This and the belt 109 feet above are about the same level as a scoriaceous conglomerate in the Atlantic cross-cut assigned to cg. 5? and about 630 feet below 6? But cf. also Belt 139.

These scoriaceous tops occur all along here.

137. Ophite, the top seamed and banded, the base a well-marked dark ophite. At 314, 2 to 3 mm., at 325, 1 mm., at 327 contact.

Arc. 15, 248-327, 79 (77+)

138. Ophite, marked for so small a flow; at 334, 2 mm., at 344, 1 mm.

Arc. 15, 327-331 Amygdaloid -355 (28)

139. Ophite, with characteristic scoriaceous top, at:

370,	379,	389,	402,	433,	443,	448,	453 feet
1,	2-3,	2½-3,	3-4,	3,	2,	1-2,	1-½ mm. mottles

Arc. 15, 355-364 Amygdaloid 459, 104 (102)

Arc. 16, 63- 92

Cf. the bed at the top of Isle Royale mine d 11

Below Conglomerate 5	(513)
" " 6 perhaps	(663)
" " 8 "	(1468)

140. Basic, amygdaloidal or scoriaceous conglomerate. Number (4)?

This may be correlated with the first conglomerate on the Atlantic cross-cut to the northwest 18 feet across, there provisionally correlated with Marvine's No. 4.

Arc. 15, 459-483+, 24 (24)

Arc. 16, 92?-115? 23

Hole 15 shows the "characteristic amygdaloid conglomerates" below Conglomerate 6 very well. They are intimately associated with well-marked ophites, and the scoriaceous character seems to be associated with the more augitic flows while the more feldspathic are more coarsely amygdaloid throughout.

Arc. 16 begins in an ophite that is growing finer and at Arc. 16, 92? passes into a scoriaceous brecciated bed like that at Arc. 15, 45-9. This correlation fits perfectly with the correlation of Arc. 14, 340 and Arc. 15, 101, and implies a dip of 51° if there is no change in strike or dip. It would require a change of 27° in strike to produce the effect of apparently flattening the dip from 56° to 51°, but the conglomerates on Section 29 seem to veer nearly that much and strike nearly N. 63° E. In case the direction of the drill holes is that much out from being at right angles to the strike the thickness should be reduced about one-tenth, to about nine-tenths of their present value. While I think some such correction is needed the amount of this correction is so uncertain that I have not done so, and in Hole 16 no correction has been applied to the beds at all.

Below Conglomerate	5	(537)?-10%
	6	(677)?-10%
	8	(1593)-?

140A. Fault clay, red clay and scoriaceous top of belt below.

At Arc. 16, 115 is a red clay sludge under which is a mixture of fine grained trap and scoria, and from 124 to 134 it continues rather soft and clayey. At 142 it is a fine grained and laumontitic trap. At 153 there are fragments of scoriaceous conglomerate and red mud and again at 192 feet, so that the boundaries of the belts are very arbitrarily taken.

141. Ophite, crushed, with scoriaceous trap?

Arc. 16, 115-124, 109? — 109?

142. Ophite with scoriaceous top, decomposed and fissured down about to 240.

At	257,	274,	284,	306 feet
Mottlings of	2,	3–4,	3–4,	3 mm.

Arc. 16, 224-314 — 90

143. Melaphyre, with 9 feet amygdaloid, tends to be a fine grained trap, faintly ophitic at the base 371.

Arc. 16, 314-375		71
Below Conglomerate	5?	(797)-10%
" "	6?	(937)-10%

144. Ophite with scoriaceous top (practically basic conglomerate) down to 394; at 417 there is red sand and at 429 feet 1 foot of red clay (fluccan). Cf. perhaps Isle Royale consolidated Bed 43.

	At 430,	444,	456,	471,	499,	504 feet
The mottles are	4–5,	5,	5,	9!	2–3,	2 mm. across

Arc. 16, 375-515 — 140

145. Ophite, amygdaloidal top only.

Arc. 16, 515-533+

146. End of Hole 16.

Below Conglomerate	5,	probably not far from	(945)-10% ft.
" "	6,	" " " "	(1095)-10%

The end is probably about 600 feet or more above the horizon of the Baltic lode.

The Arcadian section thus covers the whole of the Central group. I estimate about 479 feet in 8,500 or 1 foot in 18 or 5.65% is sediment, as against 415 feet in 6,247 or 6 feet in 15 or 6.65% on the north shore of Lake Superior (in Isle Royale). The section of the beds above through the Ashbed and up into the Eagle River series

is given by the sections in Volume I, grouped as XV and has been further explored by recent drilling of the Franklin and other companies.

The Arcadian section above given also goes quite a distance into the Bohemian Range group but not, as I believe, to Marvine's Conglomerate 3. The Arcadian was, however, reorganized and the New Arcadian drilled and has put in a shaft and cross-cut farther east in Section 29. (See Pl. IX.)[1] Taking the Central group alone it is interesting to compare this section with Manitou 7. We have 90 beds here as against 115 and perhaps a few more there. We have the Greenstone practically run out here, whereas from No. 9 conglomerate to No. 8 is practically constant when we allow for the fact that faults are likely to disturb both series—3,015 feet here as against about 2,800 feet there. In both cases, and all along the range, the amount of sediment is almost inappreciable. The succession of beds must have been very rapid. This is the last really complete section of the Central group until the Winona. From this point south the center of interest and exploration has shifted lower down—to the Bohemian Range group. That there is any reason for this in the distribution of the copper itself may be doubted, since it may be explained by the depth of glacial covering, and the accidents of development.

§13. QUINCY-HANCOCK (FIG. 43.[1])

The various sections of XV of Volume I lead us from the Franklin Junior and Arcadian to the Quincy and Hancock mines which overlook Portage Lake. This winds like a river through the range but does not seem to mark as a whole any profound break.

There is some uncertainty in the section near it owing to possible faults, but the upper beds have been well exposed.

The Swedetown Creek section exposes what seems to be the Freda sandstones. These are underlain by the Nonesuch shale group, a series of alternating brown or green flags and green to black shales, quite micaceous and exposed near the powder houses with about the same strike and dip. Then succeed the "Leopard" sandstones of the Old Hancock quarry. This seems to be the same series exposed in the creek near the Old Atlantic stamp mill opposite or lower if anything. On the average these beds dip 23° 30′ to N. 51° W., at which rate the mile covered would not amount to more than (2,100) feet.

We next come to a series of conglomerates and amygdaloids

[1] In envelope.

exposed in the Hancock vertical shaft and on the hillside near it. So far as I know no trap or amygdaloid occurs above the beginning of this shaft.

The Hancock vertical shaft begins in	
Conglomerate No. 22 of Volume I, Plate XIX.	210 feet
Amygdaloid	5
Trap	
Conglomerate No. 21 and sandstone to	291

dark red with much basic matter (1 mm. conglomerates or arkoses).

This will include, then, Marvin's conglomerates 18-22 which correspond to something like (1,200) feet of thickness according to the mean dip and should bring us down to the Hancock vein of the No. 1 shaft and of Volume I, Part II, page 83, the second amygdaloid (93) feet under the Hancock west conglomerate No. 17, just about the horizon of the old Atlantic mine. A number of sections from No. 17 down to the Pewabic lode are given in Volume I. (See also the Arcadian section, and I believe various cross-cuts have exposed it since.) The Hancock vertical shaft and various cross-cuts thereto will well expose this part of the section. Figure 43 gives a cross-section of the Quincy mine long cross-cut into the foot. The ventilation in part of this was not good, and the fumes of nitroglycerine gave me a sick headache, so that I do not feel as much confidence in this section as in some.

Sp. 17999 is from a drill hole a short way into the hanging of the Pewabic lode of the Quincy mine. The augite is in patches or interstitial areas may be of polysynthetic individuals. The average diameter of these patches is 1.3 mm. The plagioclase seems to be between Ab_3 An_1 and Ab_2 An_1 and is therefore oliogclase. Compound albite Karlsbad individuals are grouped together and are 1 to 1.2 mm. long by 0.3 mm. wide. The olivine is conspicuous and is about 0.75 mm. across. The chlorite is in botryoidal aggregates filling the cavities. The spherules show strong dispersion and the extinction is sometimes plus and sometimes minus. The thickness of the section judging from the retardation of about 400 for augite and 111 for feldspar is .017 mm. The chlorite seems to have a birefraction of about .018. It seems to be copiously mixed with zoisitic epidote whose refraction is greater than augite and about like chlorite. The olivine is all changed to iron oxides and green chloritic or serpentine substance.

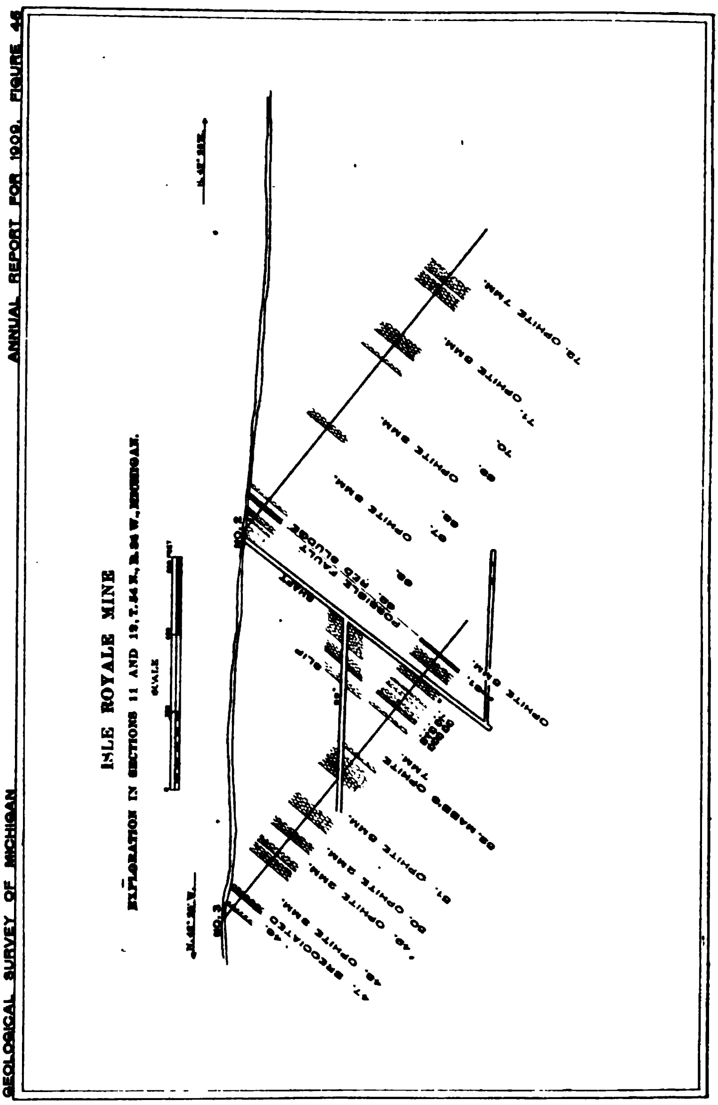

Figure 45 Geological section of Isle Royale mine showing work in Section 12, E. 54, R. 34.

§ 14. ISLE ROYALE CONSOLIDATED MINING COMPANY. (FIGS. 44 AND 45 AND Pl. X.)

Overlooking Portage Lake, the town of Houghton and the College of Mines are bluffs on which stands the property of the Isle Royale Consolidated Mining Company. The following section from their notes is one of the most detailed of the Bohemian Range group below Conglomerate 8. It is an important section because

just here the numbers to Conglomerate 1 to 8 were first assigned.[1] The section is practically complete and continuous with the exception of a small gap below Conglomerate 8, which we have patched in as shown. It is noteworthy in that this is the first extensive section in the Bohemian Range group since the Mendota and Montreal. There is a heavy ophite at the Montreal 1,608 feet down and one here about 2,000 feet down. Here it is not over 400 or 500 feet more to the Baltic conglomerate 3, while in the Mendota section it is 1,400 feet from the first ophite to the Lac la Belle conglomerate. If, however, we suppose the very thick ophite just above to be the Mabb Ophite we might get nearly accordant figures. There seems to be no reason why the Lac la Belle conglomerate may not be the same as the Baltic, and the mining done on Sections 31 and 32, T. 58 N., R. 29 W., and Sections 35 and 36, T. 58 N., R. 30 W. be at a horizon not far from that of the Baltic lode, though largely on fissure veins, to be sure.

The detailed record of the work around Houghton follows and is illustrated by Figure 44. The section (above) is pretty well completed by exposures in Houghton, studied in Volume I of these reports.

GEOLOGICAL CROSS-SECTION AND COLUMN OF THE ISLE ROYALE CONSOLIDATED. (FIGS. 44[2] AND 45.)

Abstract. *Isle Royale drill hole 4.* Paralleled by Holes 5, 7, 8, and holes from drifts in the mine, e. g., 5. 13 level S. of No. 2.

Beds 1-8 Feldspathic ophites and melaphyres
No. 3 is hanging of Isle Royale lode,—above No. 8 (483)
Bed 9. *Conglomerate 8* d 4. 990-1024 d 5. 995-6
Beds 10-17. Unexplored gap. Conglomerate 8 to drill hole 12.

Isle Royale drill hole 12.

Beds 18-21. d 12. 1-148
Bed 22. *Conglomerate* 6 d 12. 148-150
Base below Conglomerate 8 (721)
Beds 23-30. Amygdaloids and small feldspathic ophites d 12. 150-12. 365
31. *Conglomerate* 5, d 12. 365-387 (23)
Base below 6 (237)
32? and 33. Amygdaloid conglomerate -437 (50) 73
34. 5 mm. ophite (69+);
(35 & 36) 5 mm. ophite (85);
37. (4 mm?) ophite 100?; d 12. 692 and d 11. 88
Base of Hole 12 below 31 (no allowance for faulting) (305)
Ophites show mottles down to 1 mm. and less.

[1] Vol. I, Pt. II, pp. 62-63, table p. 60. Pls. XIV to XIX.
[2] Fig. 44 is in envelope.

Isle Royale drill hole 11. Laps No. 3 at bottom. 395 feet below base of a conglomerate outcrop, which is 31-33.

38. *Marvine's* Conglomerate 4 (12) d 11. 88-100
Base below base of 22 (552)
38. A. cg. & 39 3 mm. o. (90); 40 and 41 2 mm. o. (84); 42 2 mm. o. (64); all small ophites with A. cg. top.
43. Felsitic conglomerate d 11. 346-368 trace of copper.
Base below base of 38 (268)
44. 2 mm. o. (36?); 45 A. cg. & 46, 3 mm. o. (75); 47 A. cg. & 48 5 mm. o. (95); 49 to d 11. 574
49. d 11. 574 to 499; d 3. 180-274; d 9. 15-62 (94)
Base below base of 38 (568)

Isle Royale drill hole 9. Laps 3, 13 and 14 in part; crosses Mabb ophite.

50. 2 mm. o. (65); 51 5 mm. o. (115) to d 9. 232 and d 3. 463 below base of 38 (748)
52. *Mabb ophite* 8 mm. d 9. 232-451, d 3. 463-706, d 14-172, d 13. 400-513 (219+)
below base of 38 (969)
55, 56, 57, 58. Feldspathic melaphyres to d 9. 550
Base below base of Mabb ophite (99 to 183)
59. Signs of copper common horizon of Baltic lode
60.
61. Baltic conglomerate No. 3, d 9. 614-685; d 3. 879-891; d 14. 282-373 (71)

Base below base of Mabb ophite		(234)
" " " " Bed 38 Cg.	(4)	(1201)
" " " " " 22 "	(6)	(1753)

Possibly repetition of 31 to 33

62. (29);
63. 2 mm. (66);
64. S. cg. and 65 2-3 mm. (49)!?;
66. (36);
67. (33);
68. (4 mm.) 226?
69. 1 m. (20);
70. 1 mm. (30);
71. 5 mm. (173);
72. 8 mm. (213); above beds appear to be 41 to 52 repeated faulted.

Isle Royale drill hole 4. At an angle of 34°. Elevation about 930 above tide. 300 ft. E., 500 ft. N. of the W. ¼ post of Sec. 11-54-34. The indications on the sandstone conglomerate seams at the bottom and the epidotic seams at 747 ft. etc., are that the hole cuts the beds at an angle of about 64°; and a steeper dip than at right angles to the hole is required in order to make the correlation with the lode in shaft No. 6 and the conglomerate 860′ S. of the W. ¼ post of Sec. 11. Assuming the beds cut the hole at 64° we have to take .9 of the width for the thickness. This would, however, imply a dip for the beds of 71° which is too great. The true thickness is probably somewhat greater.

1. Feldspathic ophite (74+) (100?)

Trap d 4. 50-124

Fine grained at first; coarse feldspathic, 2-3 mm. mottles at 60-85, with an amygdaloid inclusion at 85, then darker, harder, finer. This may also be the first bed in No. 5, but there the glomeroporphyritic base is much more distinct, small 1-2 mm. epidotized greenish feldspars occurring on a red ground, and it is possible that a fault crossing No. 5 has brought in higher beds. Cf. Bed 92 in the Arcadian section, about 2,000 ft. below the Wolverine sandstone, Marvine's Conglomerate 9.

2. Feldspathic melaphyre (108)

Amygdaloid d 4. 124-135

Slightly porphyritic. Cf. No. 5. 87-104

Trap d 4. 135-244

Occasional pink amygdules of prehnite (?) and green flinty inclusions. The mottling at coarsest is very vague, though it can be seen to grow finer toward the base. Specks 2 mm. across of altered olivine are plentiful. Hole 5 is in the same belt perhaps between d 5. 124 and 240. Between 240 and 248 there is, however, a marked slip and this may be some higher bed. It is characteristic in No. 5 that the feldspar laths are long (2 mm., in one case 10 mm.), the chlorite flecks plain, and the core long, with epidote seams and signs that the dip is nearly vertical.

3. Feldspathic ophite (184)

Amygdaloid d 4. 244-254

Coarse, poor. Cf. Hole 5. 240-248

Trap d 4. 254-449

The augite mottling is faint: at	278,	314-354 ft.,
the grain is	2–3,	5-7 mm.

The feldspar is at 436 ft. 1-3 mm. long.

The olivine is at 314 ft. 0.5 mm., above 436 ft. 1 mm. and conspicuous.

Toward the base the hard, dense, *faintly* mottled trap with long cores is characteristic. Cf. Winona d 10. 484-615. Between 441 and 445 there is a slightly amygdaloidal seam. This heavy bed is the well-marked hanging of the Isle Royale lode, coming between it and the Grand Portage[1] in section 11, 18+81 ft.

It is well shown in Hole 8. 1-226, where also the mottling is from 5-7 mm., and in Hole 5, 240-435, with mottling

at	243,	348,	400,	405,	422 ft.
respectively	1,	7,	3,	1,	0 mm. across

Base of top of Isle Royale lode to top of No. 8 conglomerate (482)

Cf. Hubbards (542) to base, and Marvine (pp. 65-66) 10+355+7+150+ =512+

It is probable that we have used a little too large reduction factor.

4. Feldspathic ophite. Isle Royale lode and foot. Arcadian (96)

(probably a gush of the overlying). (84) to (93)

Breccia d 4. 449-455

This is the Isle Royale lode. There is copper at 440. In No. 5 the copper is at 446. It is fine grained, red glomeroporphyritic, like numerous holes in the mine running into the foot.

Trap d 4. 455-542

[1] Marvine, p. 64, the abundant small flecks of red mica of Marvine, rubellan of Rominger, V, p. 94, 114, are the altered olivine.

Faintly ophitic from 1-2 mm. at 490, up to 3 mm. at 495, then finer. A number of holes show up this. Hole 5 of 13th level, S. of No. 2 shaft shows a faintly mottled trap 3 mm. at 30, at 78 to 90 2 mm., with epidotic amygdaloid. In general the mottling gets up to 2 to 3 mm; not more, and there are prehnite bands and amygdaloid inclusions. Hole 5 on Sec. 15 is ophitic from 464 on but faintly,—2 mm. at 500. The feldspar is 0.5 mm. and the hand lens shows altered olivine. From d 5. 517-548 appears a separate flow. From d 5. 517-579 a gray amygdaloid with laumontite and calcite amygdules, then a fine trap with 2 mm. feldspar and epidote seams at 31° to hole (71° dip) and occasional amygdules 1 mm. across. Marvine's Section 11 makes this 15 to 50 lode + 69 melaphyre.

The marked red-brown character of the amygdaloid underlying it, that is the top of 5, is noted by Marvine.

5. Feldspathic ophite (160) to (180)

Amygdaloid d 4. 542-550

Marked, red. Cf. No. 5 at 516 ft. Also No. 5, on 13th level. S. of No. 6 shaft 78-90.

There are other streaks of amygdaloid at 561-567, and 583-585, with occasional coarse pink radiating prehnite (or thomsonite) amygdules to 594.

Trap d 4. 550-722

With chloritic specks. The mottles are—

at	594–612,	622–658,	686,	707 feet.
about	2–3,	5	5–7,	2 mm. across.

The decrease of mottling from 686-722 is quite uniform. Drill hole No. 5 has a poor amygdaloid at 548-551, and occasional coarse, large, pink and green (thomsonite or) prehnite amygdules to 571, that is for the upper 55 ft. corresponding to d 4. 542-594, then faintly mottled to 591, then a green amygdaloid d 5. 591-594, then occasional green and white specked large amygdules and a fine grained trap to 613, then green and white hard amygdaloid and inclusions to d 5. 613-617, then fine grained, hard feldspathic trap to 634, then veined at 59° to 42° to the core, with amygdaloid specks and faint 2-3 mm. mottles

At d 5.	687,	688,	691 feet
the grain is	3,	1–2,	3 mm. respectively the base being at 706 feet.

Then to 709 a poor amygdaloid, then a coarse feldspathic ophite whose grain at 755 and 761 feet attains 5 mm., 8 x 4 mm. respectively.

It is quite clear that this does not match No. 4 closely and either there is a rapid change in the beds or the section is somewhat disturbed by proximity to the fault on Sec. 16. This latter supposition is probably true and according to the mottles d 5 at 755 might correspond to d 4 either at 686 or at 780.

It will be noted that Marvine reports an amygdaloid 150 ft. below the Isle Royale lode.

6. Feldspathic ophite (128) to (115)

Amygdaloid d 4. 722-730. Cf. d 5. 706-709

Marked, poor; amygdules greenish white and gray.

Trap d 4. 730-850 d 5. 709 to 725-848

Chloritic specks, epidote seams at about 64° to core. There are faint, coarse 5 mm. mottles at d 4. 780 which are comparable with 5 mm. mottles at d 5. 755. This may be two close following flows or gushes of the same flow, for at d 4. 801 it seems finer and there is an amygda-

loid inclusion and at d 5. 778-781 is a coarse amygdaloid and at d 5. 783-785 is a prehnitic amygdaloid. The feldspar is about 1 mm.

7. Feldspathic ophite (113) to (101)

Amygdaloid d 4. 850-853; d 5. 848-853

Dip of amygdaloid bands 37° against core. All these amygdaloids are of one type, thin, gray, hard siliceous, coarse with large amygdules.

Trap d 4. 853-963; d 5. 853-969

Coarse massive trap, the faint ophitic mottling hardly visible; estimated at 5 mm. at d 5. 947

8. Feldspathic ophite (27) to (24)

Amygdaloid d 4. 963-975

Coarse white and gray amygdaloid

Cf. both d 5. 985-8 and d 5. 969-973

Trap d 4. 975-984; d 5. 973-985

Mottling coarse and faint

Amygdaloid (base above conglomerate) d 4. 984-990;
d 5. 985-995

Cf. Arcadian 105

END OF CENTRAL, BEGINNING OF BOHEMIAN RANGE GROUP.

The beds of Winona drill hole 10 match, (being feldspathic ophites or melaphyres with a glomeroporphyritic margin), these beds above conglomerate 8, and the green and white amygdaloid tops and inclusions hard to distinguish from them are like those met in Arc. d. 3.

9. *Conglomerate* 8. (34?) or (30±)?

d 4. (984 or) 990-1024. d 5. 995-6

From 984-990 is a transition to an epidotic conglomerate, the pebbles of felsite are also well marked. There are also sandstone beds which dip (co. 29°, 26°, 24°) about 65° against the core, suggesting that the hole may have flattened a good deal, and the correlation with No. 8 conglomerate in the west line of the section 860 S. of the ¼ post also suggests either this flattening or a steeper dip. There may, therefore, be a deduction of not over 10% to allow from the thickness. Base below top of Isle Royale lode (542) to (482)

This is a conspicuous datum plane, being the first important conglomerate for over 2000 feet, and is identified as the first below the Arcadian lode, and also the first below the Winona and King Philip. It is characteristic that the beds in the neighborhood have a rather feldspathic habit, and when they show the ophitic mottling the pattern is faint and can generally be recognized only in the large flows, not in the smaller sizes in which the augite patches are all cut up by the feldspar. Coarse amygdaloidal spots with pink prehnite are, as Pumpelly remarks, also characteristic.

10.

Amygdaloid d 5. 995-1017+

None of the recent Isle Royale Consolidated holes show the section between Conglomerate 8 and Conglomerate 6 completely. According to Marvine this is 896=566+332 or at a 55° dip (736)=(464)+(272) ft. Hubbard says 860 or (722) at a 57° dip.

But we may patch up the probable section in detail as follows, using the earlier explorations, and other records.

9. Conglomerate 8. Arcadian 106. Marvine p. 68. Yielded some copper.
Cross-section II h (12)

Covered in II h (168)

10. Just entered in Hole 5 (85)

(covered in II b) 85

Arcadian 107 is a doleritic ophite d 9. 133-266 (130) ft.

11. Amygdaloid (II b, notes of A. B. Wood) (5) (85)

(covered in II b 85)

Arcadian 108 is a clasolitic melaphyre, feldspathic
Arcadian d 9. 266-293 (26)

"Ancient Pit" or "Foster Mass" Amygdaloid II h, II i 17 (117)

12. Some copper found; brecciated in appearance, with quartz, prehnite and calcite filling the cracks, many ancient workings. It is thus 168 to 175 ft. below Conglomerate 8.

Covered in II h are 102 ft. to Capen vein

Covered in II b are 255 ft. to 24 ft. of conglomerate with sandstone on the upper side.

Arcadian 109 is a melaphyre, gray, green and epidotic.
Arc. d 9. 293-310 (17)

13. "Capen vein"[1] Foot 3+ (50?)

14. Ophite. Arcadian 111 is a marked ophite with $\frac{1}{2}$ mm. mottling (103-)
at Arcadian d 9. 335-365 (27 ft)

Marvine's section IIg shows two belts of "slightly shimmering" compact dark trap, with considerable magnetite, beneath the Capen vein, the second 75-125 ft. below. These same minutely mottled ophites occur on the north line of Section 1, well exposed near Agate St.

Arcadian 112 is a seam of sediment of basic sandstone or shale, only (227) ft. below Conglomerate 8. It is probably intimately connected with Arc. 114, an epidotic sandstone, though separated by Arcadian 113 d 3. 365-395+

15. Conglomerate (IIb) No. 7. (24)

This appears to be unusually thick

Base below base of No. 8 according to Marvine (464) ft.

See also Hubbard p. 108 and 107 510 ft. horizontally or (420)+

Cf. Arcadian 114 at d 10. 40-43

In section (II b) the next interval below Cg. 7 is covered (260) ft. down to a 3-foot conglomerate, which is supposed to be (6), so that we can not exactly tell what the intervening beds are except as the new Hole 12 informs us.

Below No. 7, i. e., Arcadian 114, there follows in the Arcadian section a series of 8 thin amygdaloidal and glomeroporphyritic flows, and three fair-sized feldspathic melaphyres; in all 804-267 (537) ft. These are not unlike the beds at the top of Hole 12, but the record probably is disturbed

[1]Marvine II h and II g apparently a fissure vein? "Seams of calcite, prehnite, laumontite and fibrous chlorite with flakes and sheets of copper."

Arcadian bed 110 a marked ophite (more so than for a long distance above) the mottling showing clear down to 1 mm., the top brecciated and reminding one of the ancient pit. The melaphyre of the Capen vein is also an ophite, and minute mottling may be seen on the N. line of Section 1.

The Capen vein may cross not only this amygdaloid, but further north Conglomerate 7. See Hubbard, Volume VI, Part II p. 132.

Underneath (II g) is a melaphyre "shimmering,"—an ophite, dark, compact, and with magnetite, apparently a heavy bed.

by faulting. Marvine's section II. g also shows only 2 fine grained amygdaloids in its lower part down to 250 below the Capen vein (205). Marvine gives a conglomerate about 500 ft. horizontally below (410) the Capen vein, which should accordingly be (410-50-103) (257 ft.) below No. 7. In IIb the interval is (260) ft. Hole 12 begins 140 ft. (less 15 ft. overburden) above No. 6, and shows three beds in these (125) feet. There may be something like 7 beds then in the interval between Conglomerate 7 and 6 which seems thus to be characterized by small feldspathic beds as follows:

16.	First amygdaloid below Conglomerate 7 (Marvine II g) shows stains of copper carbonate	50±
	There is some copper at about this level at the Arcadian in beds 115-123.	
17.	Second amygdaloid below Conglomerate 7 (II g) green, silicious, chloritic.	50±
18.	Is Isle Royale d. 12 15-50 (Amygdaloid above hole, trap)	57±
19.	Is Isle Royale d. 12 50-63 amygdaloid, -68 trap	18
20.	Is Isle Royale d. 12 68-72 amygdaloid, -120 trap	52
21.	Is Isle Royale d. 12 120-135 very epidotic amygdaloid, -148 trap	28
22.	Is Isle Royale d. 12 148-150 felsitic, epidotic conglomerate d 6	2
	Base from base of No. 7 about	257 ft.

17 and 18, may be the same bed. 16, 17 and 18 are not represented in the cores.

Isle Royale drill hole 12. At an angle of 35°. Elevation about 950 above tide, 700 ft. S., 300 ft. E. of the S. ¼ post of Section 1-54-34. About 1290 ft. across the strike from the Isle Royale lode; it should accordingly be about (1060) ft. beneath it or (518) ft. below the base of No. 8 and (722)-(518)=(204) feet above Conglomerate 6. It ought, then, according to Marvine's II b section to miss Conglomerate No. 7 by only 54 feet or so[1]. The 2 or 3 feet of conglomerate in it at 148 feet, (194) feet or so beneath, would then be the next, i. e., No. 6, which Marvine makes only 3 feet thick. The interval from 7 to 6 Marvine gives as (250) to (272) feet, however, which is considerably greater.

18. Feldspathic melaphyre d 12. 15-50 (57+)
    Amygdaloid not exposed in the hole. Trap has 1-2 mm. feldspar.
19. Amygdaloidal melaphyre (18)
    Amygdaloid d 12. 50-63
    Has yellowish amygdules of ankerite, then lower of epidote then more massive
    Trap d 12. 63-68
20. Feldspathic melaphyre (52)
    Amygdaloid d 12. 68-72
    Trap d 12. 72-120?
    Feldspathic, finer from 86 down to 113. The bottom contact is so much epidotized from 113 to 125 that the dividing line is hard to fix.
21. Feldspathic melaphyre (28)
    Amygdaloid d 12. 120-135
    Very epidotic d 12. 120-125
    Trap d 12. 135-148
    Feldspathic

[1]On the E. & W. section line of Section 1. 850 ft. W. of the center is an exposure of Cg7 at just about the right position.

22. *Conglomerate 6*, of Marvine d 12. 148-150 (2)
Felsitic, epidotic, standing at about 82° to core.
The thickness Marvine makes 3 feet, struck in II b, p. 65, and 1½ feet in II which is nearer Hole 12 while it is reported only ½ inch thick further north and was apparently not noticeable in II j, etc. But it either thickens to the south or some other has been mistaken for it.
Base below base of No. 8 (721)

23. Melaphyre (20)
Amygdaloid top apparently eroded away
Trap d 12. 150-170
Specked with pseudomorphs of phenocrysts

24. Ophite (11)
Amygdaloid d 12. 170-174
Very well marked
Trap d 12. 174-185
At first fine grained, epidotic and doleritic, at 178 there are ½ mm. mottles, and thereafter it is banded with finer and coarser mottles up to 1 mm., showing apparently irregular initial distribution. This is an exceptionally small bed for a well-marked ophite.

25. Melaphyre (probably ophite) (17)
Amygdaloid d 12. 185-192
Trap d 12. 192-202
Specked and with epidotic seams

26. Ophite (58)
Amygdaloid d 12. 202-212
Very well-marked, pumiceous or frothy for four inches, then poor and mixed with flinty epidotic trap.
Trap d 12. 212-260

The mottling is distinct.	At 224,	231,	243,	255 feet	
the grain is	1,	2,	2,	1 mm.	respectively, be-

ing coarser above 241.
Seams are numerous, parallel to the core and at 59° to it, i. e., about vertical.

27. Amygdaloidal ophite (45)
Amygdaloid d 12. 260-265
Amygdules and amygdaloidal trap d 12. 265-305
From d 12. 265-280 is a specked poor amygdaloid with small chloritic amygdules, thence to 305 is faintly ophitic and amygdaloidal or specked—it is probably near, and altered by, a fissure.

28. Amygdaloidal melaphyre (19)
Amygdaloid d 12. 305?-316
Greenish with much disseminated epidote
Trap d 12. 316-324
Specked with pseudamygdules, and with gray epidotic streaks parallel to the core

29. Amygdaloidal melaphyre (14)
Amygdaloid d 12. 324-335
Gray and white with yellow seams (of ankerite?)
Trap d 12. 335-338

30. Amygdaloidal melaphyre (27)
Quite amygdaloid d 12. 338-345
Trap d 12. 345-365

At 347-350 near a prehnite vein which is at 26° to the core, probably about vertical; brecciated at 354 also and at 357 has a datolitic look.

From 362-372 the trap is gray with yellowish specks and amygdules (ankerite?) with an indurated contact of the trap and sandstone somewhere here at about 365. Beds 27 to 30 are quite likely *not* all separate flows, but may be one general amygdaloidal bed.

31. *Conglomerate, Marvine's* 5. d 12. 365-387 (23)
Sandstone and trap d 12. 365-376
Felsitic conglomerate d 12. 376-382
Sandstone, amygdaloid and epidote d 12. 382-387

Base below base of No. 6. (237)
" " " " " 8 (958)

32. Large amygdaloid inclusion or block? about 398 (30?)
33. Amygdaloid conglomerate d 12. 417-437
With red mud matrix and black and white scoria.

Marvine makes Conglomerate No. 5 24 feet thick, evidently counting in it only down about to 387. It is, however, doubtful if the beds between 387 and 417 are an independent flow (though they may be the top of one) or only some large talus blocks, as it were, in the amygdaloid conglomerate. This horizon is notable as having beneath it the first well-marked and thick ophite for a long distance,—No. 34.

If we take this as the base of Conglomerate 5 the distance below Cg. No. 8, is 50 feet lower. This checks well with Arcadian 129. d 14. 70-80 and ophites begin pretty promptly (Arc. 132) below that.

If we count 31 to 33 together it has about the same thickness, lithological variation and small and rather feldspathic beds above and a well-marked 5 mm. ophite below that the Baltic conglomerate (No. 3) has, and it *may* be a repetition by faulting of the same bed, but there is no reason why there might not also be a rhythmical occurrence of similar conditions.

34. Ophite 4 mm. (69+)[1]
Amygdaloid merged in the overlying amygdaloid conglomerate
Trap d 12. 437-506
At 462, 469, 477, 480, 484, 487, 501, 506 feet the grain
is 2, 3, 2-3, 4-5, 3-4, (seam) 2, 1 mm. respectively.
Down to 462 is specked, decomposed. At 487 a strong seam nearly parallel to the hole may well cut out a little of the bed or have displaced a block.

35. Amygdaloidal conglomerate ? d 12. 506-510 4
A well-marked amygdaloid with yellow-green epidote sediment gradually passing into amygdaloid. This is hardly far enough from Conglomerate 6 to be Conglomerate 4, which is according to Marvine (536) feet below.

Base below base of Conglomerate 6 Bed 22 (360)

36. Ophite 4-5 mm. (81)
Amygdaloid d 12. 510-523
Transition to amygdaloid conglomerate
Trap d 12. 523-591
At 525, 530, 534-539, 544, 551, 560, 562, 565, 574, 578, 587 ft. the grain
is 0.5, 1-2, 2 , 3-4, 2-3, 4-5, 3-4, 4-5, 3-4, 2, f. g. respectively

[1] Not faulted, about (100?).

At 565 and 580 are seams at about 45° to the core, (nearly vertical probably) with prehnite, quartz and copper. Otherwise the grain is extra coarse, extra close to the bottom. This is equivalent to 26 ft. of the dark melaphyre under (358) ft. "covered" of Marvine's cross-section II.

Base below base of Conglomerate 6	591-150	(441)
according to Marvine	358+26	(394)

No. 34 may be exposed in Marvine's II e.

No. 32 is exposed in Marvine's II b, and is made about (251) feet below Conglomerate 6, (in the section on Plate XV), 361 or (292) by his table. The correlation is sufficiently close, but it is not apparent how the figures of Marvine's table which do not check so well were obtained.

Underneath this bed No. 34 begins a series of good sized ophite beds, well exposed in the Baltic location town site.

37. Ophite 3-4 mm. (101+) (90?)

Amygdaloid d 12. 591-610

Specked with pink and white amygdules on dark ground, to 594; epidotic, brecciated -604 (breccia again at 610).

Trap d 12. 610-692+

The mottling not uniform nor plain, 1-2 mm. at 653 and up to 3-4 mm?, then 1-2 mm. at 686, 2 mm. at 692. It is brecciated at 610-616, much seamed, and especially full of red slips about 671 where the alteration is so great that the pattern of the mottling is lost down to about 682 feet. While 10 or 20 feet should be added to the bottom before the contact comes it is probable, judging from the pattern of the mottles, that that would make the flow thicker than it really is, and that there is some repetition by faulting at about 671.

Bottom of Hole 12 below base of Conglomerate 6

	(692-150)	(542)
(34)	Conglomerate 5? (692-437)	(255)

Top of Hole 11 below top of Hole 12 770 or (630) ft.

The top of Hole 11 is also about 480 (395) below the base of a conglomerate outcrop, which is presumably (Beds 31 to 33). It should therefore lap No. 12 and begin in a 3-5 mm. ophite which may well be the one No. 11 ends in, that is No. 37. There is probably less faulting. In No. 11 the grain runs more uniform.

Isle Royale drill hole 11. N. W. of N. E. quarter, 3850 ft. N., 1760 ft. W. of Sec. 1, at an angle of 35°. Elevation about 900 ft. A. T.

37, again.]

Ophite d 11. 30-88 (58+)

Amygdaloid not shown

Trap (About 100)

At	30,	38,	55,	66,	75,	85 ft. the grain
is	2,	2-3,	3-5,	2,	1,	0.5 mm.

At about 55 ft. in it, it is as coarse as anywhere.

There are seams at 10° to core, and at 38 and at about 77 gaping chlorite seams parallel to core. Otherwise it is not much broken. The same bed as the bottom of 12 and the 53 and 47 feet of melaphyre, the country rock of the "New vein" in Marvine's section II+37 ft. amygdaloid?

38. Amygdaloid conglomerate d 11. 88-100 (12)
Conglomerate 4 of Marvine's Section II, who also makes it 12 ft. thick.

Base below base of Conglomerate 6, by addition (572)
from end of No. 12 (554)
Marvine (533)

39. Ophite 3 mm. (78)
Amygdaloid d 11. 100-110
There are some calcite seams
Trap d 11. 110-178
At 118, 131, 141-147, 155 164, 176, 178 ft. the grain
is 1, 2, 2-3, 5 (coarsest), 2, 0.5, 0 mm.
Cf. 17 "amygdaloid" and 23 "dark and rough melaphyre" of Marvine Section II.

40. Amygdaloid conglomerate d 11. 178-202 (24)
The matrix is red or light brown mud or calcite, with red and blue-black angular scoria.

41. Ophite 2 mm. (60)
Amygdaloid is included in amygdaloid conglomerate above.
Trap d 11. 202-262
At 215, 222-231, 240-246, 250, 255, 261 ft. the grain
is 2, 2-3, 1-2, 1, ½, ⅓ mm.

42. Ophite 2.5 mm. (64)
Amygdaloid d 11. 262-284
The contact is well marked by a brecciated amygdaloid almost an amygdaloid conglomerate.
Trap d 11. 284-346
At 288, 293, 301, 310, 315, 325, 334, 340, 344 ft. the grain
is ⅓, 1, 1-2, 2-3, 2, 2-finer, 1, ½, smaller
At 308 a vertical seam parallel to the core, probably along a columnar joint, which jointing appears elsewhere, is normally faulted by one at 70° or less to the core.

43. Conglomerate d 11. 346-368 (24)
There is copper in a little seam in a felsitic pebble of the conglomerate, which has felsitic pebbles to 351; there is an amygdaloid conglomerate to 368.

Base below base of No. 4 (Bed 38) (268)

This does not appear in cross-section II or any of Marvine's sections. He has given it no number and it occurs between 3 and 4 of his numbering. But this hole and the Atlantic cross-cut and numerous other partial sections show that there are a number of conglomerates between Marvine's Nos. 3 and 4, mainly amygdaloidal.

At d 11. 368 a seam nearly parallel to the core is crossed, with a transition to a 1 to 2 mm. ophite rather faint and feldspathic.

44. Ophite 2 mm. 368-404? (36)
At 368, 378, 385 ft. the grain is
1-2, 2, 1 mm.
At 388 amygdaloid specks and brecciated cavities with crystals occur and the contact is uncertain.

45. Amygdaloid conglomerate d 11. 404-419 (15)

46. Ophite 3 mm. (60)

Trap d 11. 419-479?

At 422, 427-432, 441, 454 464, 474, the grain is
1, 1-2, 2, ab. 3 (coarsest), ab. 2, 1 mm.

Cf. Hole 3. 33-70 (37) with a mottling of only 2 mm.

Exact base not clear (3 or 4 ft. trap at 482 ft.)

47. Amygdaloid conglomerate d 11. 479-491 (12)

With a reddish brown matrix and black and white amygdaloid pebbles.

Hole 3 at 70-86 is brecciated, noted as perhaps sedimentary, not so well-defined as in 11, and perhaps there is here something cut out by a fault.

48. Ophite 5 mm. (83)

Amygdaloid d 11. 491-502

Greenish to 497 and marked in spots

Trap d 11. 502-574

A banded ophite, bands with 1 to 0.5 mm. grain alternating and amygdaloidal about 514. It is notable that in Hole 3 I did not make the grain over 3 mm.

At	522-526,	534,	541,	545,	553,	558,	565,	567,	570 ft.
the grain averages	2-3,	3,	4,	5,	3, 2-3,	2,	1,	½ mm.	

Base below base of Conglomerate 4 (Bed 38) (474)

Hole 3, 86-180 94

49. Ophite 2 mm. (92)

Amygdaloid d 11. 574-580 d 3. 180-202

Brown and white, soft, above; cold, gray, hard epidotic below, then trappy, then a streak of epidotic amygdules at 580.

This may possibly be the 39 ft. of amygdaloid of Marvine's Section II.

Trap d 11. 580-599+, 3. 202-274

Fine grained to 586, then slightly amygdaloidal with pink amygdules and streaks to 598. Cf. d 3. 224-228. At 599 is a cross-seam with quartz and prehnite, then copper and epidote of later formation.

Base of Hole 11 below Conglomerate 4 (499) ft.

The gap from d 11 to d 9 may be nicely bridged by Hole 3.

Isle Royale drill hole 9. At an angle of 35°. Elevation about 900 above tide, 1400 ft. S. and 1050 ft. W. of the N. E. cor. of Sec. 1-54-34. It should therefore begin shortly above the "147 feet covered" of Marvine's section II. It is 780 ft. (640) below 11 which it should therefore just about lap. It probably therefore begins in 50, though it may be 49.

49. (continued). 2 mm. ophite (75+)

Trap d 9. 15-52 d 3. 180-274 (94)

Begins in a 2-3 mm. ophite, jointed at 22° and seamed at 57° to the core. Finer at 40 (1-2 mm.). As the grain is decreasing the full thickness may be anything more than 70 so far as this hole is concerned, so we take it from Hole 3.

Base below base of 4 by addition (562)
or by section (594)

If the amygdaloid below is the "20 ft. of epidotic amygdaloid" of Marvine's section II the corresponding distance would be (558),—a good correlation.

50. Amygdaloidal ophite 2 mm. (65)

Amygdaloid d 9. 52-84, d 3. 274-287

Marked with white amygdules, reddish above, greenish gray epidotic below, so at 69, and then about 84 brecciated and alternating with trap. The amygdules are small. Seams nearly across the core are faulted.

Trap d 9. 84-117, d 3. 287-336

With spots of amygdaloid, with 1-3 mm. amygdules and pink and white breccia filling, containing crystals. This seems to resemble No. 49 in Hole 11 a good deal, and I should not be surprised were it the same, the repetition being due to the faulting of which there are signs. In that case the first bed in 9 would be equal to 49. They are both ophites. The match of this bed in Hole 9, so far as thickness goes with that in No. 3 (62 ft.) is very good.

51. Ophite 5 mm. (115)

Amygdaloid d 9. 117-129, d 3. 336-348

Gray, coarse, with epidote and quartz and calcite amygdules. In No. 3 it is red above, gray below.

Trap d 9. 129-232, d 3. 348-463

There are seams parallel to the core, joints across core and at 12° to it.

At d 9.	146,	156,	160,	171,	181,	187,	195,	197,	206,	209,	214,	217 ft.	the
grain is	2-3,	3,	3+,	3-5,	4-5,	5,	4,	5-3,	2-5,	1½,	1,	1 mm.	

Below 220 it is fine grained with amygdaloidal streaks.

It is reached in the west cross-cut of Sec. 12 shaft. (Fig. 45).

Drill Hole 3. 336-463 in which the grain is also (5 mm.) a very good match.

At d 3.	362,	368-381,	394,	434,	448,	452 ft.	the grain
is	2,	2,	5,	3,	2,	1 mm.	

52. Mabb ophite 7-8 mm. (219)

Amygdaloid d 9. 232-236

Red and white bands nearly straight across the core.

Trap d 9. 236-451

Specked, fine grained to 244, then rather coarser, but at 260 a rather sudden combination of coarse 7 x 4 mm. mottles and white amygdules, the trap epidotic, then specked finer and redder, the mottles irregular, in spots coarser, some seaming parallel to the core at 277 but no obvious great jump. There is a datolitic look near 281 and specks of copper in an amygdaloid seam. Seams and joints occur at right angles and nearly parallel to the core, also one at 64° and one at 59° are cut by one parallel to the core or vertical. Near d 9. 312 the mottles become coarser and more settled, so that for the lower half the grain may well be made out thus:

At 312, 316, 326, 331, 339, 345, 354, 360, 367, 383, 395, 404, 413, 422, 428, 433, 451 ft.

7-8, 7, 8-9, 7, 7 (5-10), 5, 5-7, 5, 5, 4-5, 3-5, 3-4, 3, 2, 1, 0.5, base

This heavy and coarse ophite is a fairly good datum plane down to the Baltic location. Possibly it continues north to the Mendota.

Cf. in Hole No. 3 463-706=(243)

14 top down to 131 or 172

13 from 400 to 513, part removed by a fault.

In the Superior trench it was exposed 600 ft. east of the center and 300 ft. S. and at the Baltic location close to the Mine office.

It is exposed in the old Mabb workings and dump and along the N. line of Sec. 6-55-33 and the 8 mm. mottling is plain, being beautifully brought out in slightly weathered masses from the old dump. It is also exposed in the N. W. end of the trench which runs N. W. from the S. E. corner of the S. W. ¼ of the S. E. ¼ of Sec. 11-54-34, and elsewhere. See Rominger Vol. 1, p. 112.

Base below base of	(50) d 9. 15-52		(399) ft.
" "	(38)	4 at 11. 100	(967)
" "	(31)	5 at 9.387	(1248)
" "	(22)	6 at 9.100	(1535)

At the Baltic location this distance seems to be about (1620) feet depending somewhat upon the exact dip assumed.

In the west cross-cut of section 12 shaft (Fig. 45) all above 165 feet from the shaft, or say 190 from the foot of the shaft to 440 ft. is the ophite, the top amygdaloid being about 40 ft.; at 222 ft. in the grain is about 7 mm.

Here and in No. 3 hole, however, a small bed of ophite (d 3. 673-706) 33′ intervenes between the Mabb ophite and the sandstone bed 54, but in the cross-cut at the top of the 44 (34) feet between the basic sandstone and the base of the Mabb ophite is a strong fluccan seam, dip 63° strike N. 50° E, the dip somewhat steeper than the formation.

Such a seam acting as a slide plane might easily cut out of the record the bed in No. 9 or may introduce an entirely new repetition of beds, by which for instance 54 would be equivalent to 38.

53. 2 mm. ophite (33)

Amygdaloid I. R.	d 3.	673-679
Amygdaloidal trap	d 3.	679-686
Trap	d 3.	686-706

1-2 mm. mottles at 694

Drill hole 3 is horizontal into the hanging from the mine, lower level has 166-194 trap and at 207-209 amygdaloid.

54. Basic conglomerate d 9. 451-453 sandstone (2)

The dip is about 64° against core,—very likely it is nearly vertical. There is only a little of this but it is quite persistent. Cf. d 14. 131-141 and 172-3 d 3. 706-722 and the bed about 100 ft. (80 above) N. of Sec. 12 shaft in the west cross-cut. It appears also in horizontal drill hole 3 from the level where it comes at 161-166, dip at 59°; also horizontal drill hole 2 at 152-162. There are seams at 72°. Cf. also the conglomerate in the Superior trench 590′ from the N. W. end.

55. Feldspathic melaphyre (18)

Amygdaloid d 9. 453-456

At 456 an epidotic, clasolitic seam.

Sample of water (1.) from this. See Chapter VII.

Trap d 9. 456-471

Fine grained, but with feldspar 1 mm.

Cf. d 3. 722-743 (21)

From 148-161 is coarse greenish amygdaloid with pink amygdules. Also d 14. 141-172

55, 56, 57 and 58 are all small flows, feldspathic (feldspars 1 mm.) and closely allied, resembling the beds above 31 and 22, Conglomerate 6 rather than the ophites which are common below. I should not be surprised to find that 54 was Conglomerate 6 repeated by faulting.

56. Melaphyre (15)
Amygdaloid d 9. 471-482
Red and white, markedly prehnitic.
Trap d 9. 482-486
Cf. d 3. 743-752 (9)
The horizontal drill hole 3. 161-115 seems to correspond to 55 and 56.

57. Feldspathic melaphyre (14)
Amygdaloid d 9. 486-494
Reddish at top, greenish at bottom.
The reddish basal amygdaloid is glomeroporphyritic like the bed under the Isle Royale lode with small 1 mm. green feldspar crystals on a red ground. The same occur in horizontal drill hole 3 at 24, 58, and 77.
Trap d 9. 494-510
Coarser with occasional red bordered or green light amygdules to d 9. 502 ft. then finer. From 44-77 above the Sec. 12 shaft or 100′ from the foot wall.
Cf. d 3. 752-790.

58. Amygdaloidal melaphyre (9)
Amygdaloid d 9. 510-519
Upper contact uncertain, perhaps part of 57, coarse.
Compare d 3. 790 with copper -811, also d 14. 180-205.
Beds 57, 58 and 59 may be compared with 77 ft. of "gray" melaphyre of Marvine's Section II. The recurrence of feldspathic melaphyres after a series of ophites is notable.

Feldspathic melaphyre (31) (40)

Amygdaloid d 9. 519-529
Upper 2 feet marked
Trap d 9. 529-550
More or less streaked with gray amygdaloid, feldspathic.
Cf. d 7. 811-834 more or less amygdaloid
d 14. 205-238 also feldspathic melaphyre
Horizontal drill hole 3 has from 29-115 beds tending to be glomeroporphyritic covering the suite 56, 57, 58 (14) + (9) + (31)
At 58 ft. a clay slip which also appears in the cross-cut is all there is to represent the top of 58. The top of 57 may be represented by a clay slip at 76 or prehnitic amygdaloid spots from 83-86. In the cross-cut this was the main belt of trap between the shaft and the conglomerate bed 54.

59. Melaphyre Baltic lode horizon (41)
Base below base of Mabb ophite direct 150
by adding 183
Amygdaloid d 9. 550-560
Trap d 9. 560-591
Cf. d 14. 238-282, copper at 264, mainly epidotic and amygdaloidal. Near 580 a clasolitic seam nearly parallel to the core making only a 20° angle with it is cut, and at 592 ft. there is a speck of copper. Near 591 it is brecciated and glomeroporphyritic, but there is no defined amygdaloid to the trap beneath, which may be a part of this.
Cf. d 3. 790-795, which also has a speck of copper as well as 834-845.
This is the belt in which the I. R. Sec. 12 shaft (Fig. 45) is sunk, and horizontal diamond drill hole 3 begins in it 209 or (164) ft. below the Mabb ophite, passing the amygdaloid at 20-29 ft. The west cross-cut remains in the lode for 30 ft.

60. Melaphyre (23)

Trap d 9. 591-614

Cf. the "21-foot amygdaloid" of Marvine's Section II.

61. Conglomerate (3) d 9. 614-685 (71)

Cf. Belts 31 to 33 and 43 to 45, also d 3. 879-891 d 14.282-353-373

A well-marked felsitic conglomerate, dip nearly at right angles (78°) to hole, at 628 ft. 2 ft. of sandstone with amygdaloid scoria, then nearly amygdaloid to 642, then sandstone and felsitic conglomerate with calcite cement passing into amygdaloid conglomerate at base, *very much like* Beds 32 to 34 and about the same thickness. Both have small amygdaloidal beds above, both have an ophite below but rather different in size, but while it is barely possible that there is a repetition by faulting, there can be no question that this is the Conglomerate numbered 3 by Marvine 1486 (1201) feet from No. 4. It is below the base of the Mabb ophite (685-451=234) ft. by addition 268

Hence below No. 4 967+234 (1201), and Marvine makes the thickness 70 ft.—a remarkably close agreement in both items.

Hence below the base of No. 6 (1201+552) (1753)

A corresponding distance at the Baltic location from No. 6? to the Baltic conglomerate is (1964) feet.

Cf. I. R. d 3. 879-891, which is largely a fluccan—a fault. This was also visible in the east cross-cut of Section 12 shaft, about 50 ft. beneath the shaft with a few boulders or residual nuggets of copper. It had a dip of 52°. The same faulting also disturbs Hole 10 so that its record is not worth anything as a consecutive records of beds. Hole 2 is perhaps a little better. Hole 2, 30-82 or to 106 matches this Belt 61, i. e., d 9. 614-685 quite well, having the same felsitic top, sandy streaks, amygdaloidal base and trap or amygdaloid intercalations.

Horizontal diamond drill hole No. 3 begins just above this conglomerate and runs 209 ft. up to the foot of the Mabb ophite, and can be correlated pretty well with No. 3 and the cross-section. In all these one bed occurs under the Mabb ophite that does not occur in 9.

62. Melaphyre (29)

Trap d 9. 685-690

A mere fragment of a sheet into which 62 has eroded?

d 2. 106-114
d 14. 373-398 (25) and perhaps also
d 14. 430-458
514-543
547-572

63. Ophite 2 mm. Cf. (42) (66)

Amygdaloid d 9. 690-694
Trap d 9. 694-749
At 698-703, 708, 723 ft. the grain
is 1, 1-2, 2 mm. From 733-749 ft. is finer.
Cf. d 14. 458-514, which is also a 2 mm. ophite
Basal amygdaloid ? 749-756

Brecciated, red and mixed, like a certain phase of the Houghton conglomerate.

Cf. Hole 2, 114-216, which has up to 2-5 mm. mottles, apparently equivalent to the bed at the end of the east cross-cut, e. g., at 210 ft. horizon-

tally beneath the shaft. The sandstone and conglomerate at the end of d 9 from 756 on, that is 71 ft. below the main Baltic conglomerate does not appear in Holes 2 or 3 or the east cross-cut of the Sec. 12 shaft, or No. 14.

Along here the faulting makes a continuous record almost impossible. The shear zone seems in Hole d 14 and perhaps d 9, as also in the Superior trenches, to have spread the Baltic conglomerate, over a broad area as it seems to have spread the Mabb ophite in Hole 10.

Below this horizon of Cónglomerate 3 the disturbance approaching the great fault zone which runs along the south border of the range is so great that though traversed by Holes 10, 2, 14 and exposed by trenches on the Isle Royale and Superior properties, no consecutive order of beds can be made out with any safety. The only thing to do is to give each record with occasional comparisons. Hole 2 seems as little disturbed as any of them.

64. Amygdaloid conglomerate. Cf. 45 (11)
d 2. 216-227
Brecciated and with white fragments on a red ground.

65. Ophite 2-3 mm. Cf. 46 (38)
Trap d 2. 227-265
Brecciated, mixed and decomposed brown trap -244, at 245 the grain is 2-3 mm., and it is ophitic to 251, then to 265 finer grained and brecciated.

66. Melaphyre (36)
d 2. 274-281
Decomposed, full of calcite seams, fine grained at 308, spots of chloritic amygdules -310

67. (33)
Amygdaloid
Prehnitic at 310, poor to 325
Trap d 2. 325-343 (28)
Veined at 327-329, fine grained and red at the bottom.

Base below base of Conglomerate 3 343-106? (237)

68. Ophite (4 mm.)? Cf. (48) (Unfaulted about 100 feet thick?) (226?)
Amygdaloid d 2. 343-364
Trap d 2. 364-569

At	371,	387,	396,	413-423,	452,	470-510,	519,	541,	554-9,	567 feet	the grain
is	1,	2,	1-2,	2,	3,	3,	4,	2,	1,	½ mm.	

At 408-413 and 452 there is much veining, and the thickness of the belt compared with the size of the mottling suggests that there is either much faulting or the dip has flattened very materially, the former being most probable, and if so it must be of the type that drops the lower or southeast side down or raises the northwest side for this would produce the unsystematic distribution of grain and exaggerated thickness of belt.

69. Ophite 1 mm.
Amygdaloid d 2. 569-580
Marked contact; the trap above has a red base, the amygdaloid is poor.
Trap d 2. 580-589

At	582	and 586 feet	the grain
is	½	"	1 mm.

70. Ophite 1 mm. Cf. (50) d 3. 274-336 (30)
d 2. 589-619
At 609 ft. the grain is 1 mm.

71. Ophite. Cf. 51 (173)
Amygdaloid d 2. 619-621
Like that at 569 and probably the same thing, not lifted up quite so much.
Trap d 2. 621-792
Trappy; then at 627—amygdaloid and mixed ophite and amygdaloid, the latter marked at 630-633.
Veining frequent, e. g., at 690, 723, 733 ft.

At	706,	737,	755,	768,	778-784	feet the grain
is	4,	5,	2,	1–2,	1	mm.

This is evidently much disturbed and quite likely Belt 51 or some higher belt repeated, as is shown by the irregularity of the grain.

72. =52 ? the Mabb ophite 213+
Amygdaloid d 2. 792-822
Marked black and white
Trap d 2. 822-1005
Fine grained -827, at 837 amygdaloidal and ophitic—grain 2 mm., at 855 3-4 mm. but still amygdaloidal. Cf. the upper part of the Mabb ophite at d 9. 260

At	868,	889,	894–902,	955,	965–970,	1005 ft. the grain is
	4,	5,	7,	8,	5,	8 mm.

This I believe is a repetition of the Mabb ophite, and we can correlate backward pretty well up to the Baltic conglomerate. So that there may be a big shear at about this point causing a repetition of the series. This may lie the same side of the fault as d 14. 572-813 which may also be a repetition of the Mabb ophite. Assuming this to be the case we should get a strike for the Mabb ophite on the S. E. side of the fault of N. 70° E, which is about the direction of the eastern sandstone contact.

The conglomerate d 14. 813-825 would then correspond to 54.
d 9. 451-453 and d 14. 131-141 or 172-3
d 14. 825-866 a feldspathic melaphyre would correspond to d 9. 453-471
d 14. 866-887 to 56 and 57, d 9. 471-510 and both have a glomero-porphyritic tendency
d 14. 887-904 } Brecciated and the breccia
d 14. 904-951 } would have to represent the interval to conglomerate 3 d 9. 510-614
d 14. 951-993 will be d 9. 614-685 a repetition of conglomerate 3.

d 14. 993-999 2 mm. ophite may be a fragment of 63, while the eastern or Jacobsville sandstone is apparently reached as a transition with no notable fault at 999, the transition being at 999 to 1001.

In other words d 14. 572-999 is a fairly solid block of repetition of the upper part of 14. But as we come into the bay made by the eastern sandstone in Section 12 if we are to fill it in this way we must suppose in Hole 2 that a still larger block has dropped or the same block been more spread out. As a matter of fact we find in Hole 2 good matches up to the very much faulted veined and disturbed and strung[1] out bed d 2. 343-569, at which point some of the faulting if not all may occur, but there are fair

[1]By stringing out I mean this: If a bed which should be cut at right angles by a hole plunging to the S. E. is sheared so that the N. W. side is lifted more than the S. E. side its apparent thickness along the drill core will be much greater and judging by the grain and other tests, abnormally great.°

matches even above. The presumption is then that while the main axis of shearing is about at this point, there is some uplift clear up to the Section 12 shaft, in which there seem to be seams striking more easterly than the shaft and steeper. In Hole 14 the evidences of shearing are striking up to 358 ft. from 572 ft.

Isle Royale drill hole 10. Seems to show a few beds much strung out and disturbed by slip faulting. It is at an angle of 32° to S. 64° E. Elevation about 900 A. T. 1000 ft. W. 600 S. of the E ¼ post of 1-54-34.

(a 59?) Ophite, 2-3 mm. (37+)

Amygdaloid d 10. -54

Much shattered, all calcite and laumontite

d 10. 41-48, coarse to 54

Trap d 10. 54-77

At 57 the grain is 2-3 mm., then finer.

(b 58) (23)

Amygdaloid d 10. 77-87

Red to 82, greenish to 87

Amygdaloidal trap 87-99

Coarse pink and white feldspathic, with large amygdules.

Trap d 10. 99-100

(c 57) Amygdaloidal melaphyre (19)

Amygdaloid d 10. 100-119

Gray, coarsely amygdaloidal d 10. 100-108

More reddish d 10. 108-114

With 1 mm. phenocrysts of red plagioclase d 10. 114-119

(d 56) Amygdaloidal melaphyre

Laumontitic and irregular d 10. 119-133

Feldspathic with pinkish amygdules d 10. 133-151

(e 55) Reddish; more compact d 10. 151-155

Yellow-green epidote d 10. 155-159

Slips parallel to the core and about 26° to it are faulted by another set also at about 26° to it. The northerly displaces the westerly, assuming the slips parallel to the hole to be nearly vertical. The trap remains feldspathic, amygdaloidal and decomposed to 186 ft.

(f 54) Slip at 186 with banded clay at 56° to the core, that is vertical. This undoubtedly marks a considerable fault. The beds above remind one of those just beneath the Mabb ophite, while below there is a sudden jump to the middle of the heavy ophite with 5-7 mm. mottling. Other slips probably parallel to it and also vertical occur at 192-195 ft. and 225 ft.

(g 72 & 52)

Mabb ophite d 10. 186-663

At 186, 199, 203, 205, 213, 227 feet the grain

is 5-7, 8, 8, 5, 6, 3-5 mm.

which may well pass for a fragment of the Mabb ophite, then there are pink seams at 45° to 31° with the core. At 239-243 it is also full of clay slips at 22° with and parallel to the core, but these are very likely merely the result of shattering along the main displacement as the grain does not seem very much broken.

At 247, 256, 268 feet the grain
is 5–6, 5–8, 5 mm. and there are seams between 256 and 261 and at 268 ft. a heavy 3-ft. seam.

At d 10. 273 the grain is 3-4 mm., and at 277-280 it is seamed. At 282 the grain is 4-5 mm., and at 290 are seams; at 290-296 and 300 the augite grain is 7 mm., and 4 mm. with amygdaloid spots, reminding one of the top of the Mabb ophite. From 311-313 is a vein parallel to the core. At 316, 319-328 ft. the augite grain is 4-5 and 7? mm. respectively. There are joints at 19° and 45° to core, and about 365 a seam at 31°. At 374 the grain is 3-5 mm. At 378 is a seam parallel and at angles to the core. At 391 are amygdaloid specks. At 398 the augite grain is 7 mm. At 410 it is decomposed. At 412 the augite grain is 3-5 mm. At 416 it is much seamed both at 31° and 45° to the core and probably both vertical.

At 422, 430, 458, 462, 475, 498, 502, 514 ft. the grain
is 7, 5–8, ab.5, 5–7, 7, 5, 5, 3–5 mm. and there are seams at 430, most notably at 38° with the core, at 462 at about 39° with the core, and at 474 at 51° and at 494 both at 26° and 39°.

The effect of the faulting seems to keep the hole in about the same horizon. Beyond this I am inclined to think that the faulting gains and we are passing into higher horizons unless there is actual overturn.

At 526 and 531 it is specked and seamed with pseudoamygdaloid specks.

At 536 there is 1-2 mm. feldspar and amygdules.

At 538 the augite grain is 2-5 mm. A seam nearly perpendicular to the core, also fractures at 59° to it. Specked and amygdaloid to 571, about 575 the augite grain is 5 mm. But at 580-588 it becomes specked and more and more so and amygdaloidal and browner as though it were passing *up* into an amygdaloid slowly. The banding of the amygdules makes an angle of only 15°-20° with the core to 663. All along to 618 there are indications that the amygdaloid is being cut obliquely at 31° or so and that the hole is rising. The fact, too, that we remain in amygdaloid from 588-663 points to a very oblique crossing of the amygdaloid.

(h 51) Ophite (106)?

Trap d 10. 663-712

At 671, 675–678, 683, 691, 701, 706, 712 ft. the grain
is 1, 1-2, 2, 1, 1–2, 2, 3–4 mm.

Amygdaloid d 10. 769

Finely developed from 691 down, amygdaloid specks appear. This appears also to be cut in inverse order and obliquely. The grain would indicate only 100 ft. or so. Seams at 40° to core may be vertical.

(i 50?) Ophite d 10. 769-803

At 772, 787-790 the grain
is 0.5, 1 mm.

At 783 the seam at 31° is faulted by others and at 796–803 are heavy veins nearly parallel to the core.

If inverse order continues these might perfectly well be Beds 51 and 50 respectively.

Isle Royale drill hole 13. Near (340 ft. W. 280 ft. N. of it) the S. ¼ post of Sec. 11, T. 54 N., R. 34 W. At an angle of 45° to the S. E., *about* at right angles to the strike. The projection crosses the line 116 ft. W. of the ¼ post. Elevation 375 above Lake Superior. It is probably so near at right angles to the strike that no correction is necessary.

1. Drift. Till full of boulders. 85 (60)
2. Ophite 58+

   Trap d 13. 85 to 153

   At top with spots of white amygdules with a green and red base or gray feldspar laths on a red base, and chloritic amygdules.

   At 117 to 134 and 143 a 2 to 3 mm. respectively 2 mm. ophitic mottling.
3. Ophite 81 (81)?

   Amygdaloid d 13. 153 to 159
   Trap d 13. 159 to 234
   At 175–9, 191, 209, 222, 234 feet the mottles are
   1, 2, 5?, 1, 0 mm. respectively

   Along about 209 are many calcite seams, some at 59° to the core, which may be near vertical, and be faults disturbing the grain which soon often grows finer.
4. Ophite 118 (118)

   Amygdaloid d 13. 235 to 239
   Trap d 13. 239 to 353
   At 253, 270, 283, 310 (center? finer below), 337, 353 the mottles are 2, 2–3, 3, 5, 2, 0 mm.
5. Melaphyre (feldspathic?) 44 (44)

   Amygdaloid d 13. 353-357
   Trap d 13. 357-361
   Amygdaloid d 13. 361-365
   Trap d 13. 365-397
   Specked from d 13. 383-397
6. Fault breccia (or conglomerate?) 397–400

   This is an obscure bed, very red and brecciated, and may not be a conglomerate, merely a fault breccia. If it is a conglomerate the grain below shows that it must rest on an eroded land surface. But is probable that in any case there is a big slip here as half the bed below is absent.

[52]. 7. The Mabb ophite. 113+ top removed (230?)

   Trap d 13. 400–513
   Begins coarsest; at 405, 433, 472, 499 ft. the mottles
   are 8, 5, 3, 1–0 mm. respectively.

   It is much veined and seamed; one set nearly parallel to core, probably vertical or nearly so, striking S. E.; another nearly at right angles, at an angle of 71.5° with core, 63.5° with vertical perhaps. If this is the Mabb ophite it is the bed at the top of Hole 14 and occurs quite persistently a short distance above the horizon of the Baltic Lode.

   In Holes 14, 13 and 3 the normal rate of increase of augite grains A appears to be for the Mabb ophite respectively 1 mm. in 13.8, 13.2, and 15.8 feet.

8. Ophite 27 (27)

Amygdaloid d 13. 513-519

Not marked but fine grained to 527

Trap d 13. 519-540

At 527 to 534 faintly ophitic, with two sets of pink laumontitic fissures at right angles to each other and at $33°\frac{2}{3}$ and $56°\frac{1}{3}$ to the core.

9. Ophite 44 (44)

Amygdaloid d 13. 540-548

Veined; coarse; epidotic.

Trap d 13. 548-584

2 mm. mottles at 565 ft. Seams are at only 10°-15° angle with core.

10. Feldspathic melaphyre 42 (42)

Amygdaloid d 13. 584-595

Light gray-green amygdaloidal

Trap d 13. 595-626

This is slightly coarser; 1 mm? at 605 feet, and glomeroporphyritic with feldspar aggregates. Towards the base there is a sandy clasolitic seam nearly at right angles (79°) to the core.

In Hole 14. 132 to 282 we seem to have under the heavy ophite a group of somewhat similar extra feldspathic traps.

The suggestion seems plausible that in d 13 the Mabb ophite has not been as much upheaved as in d 14; in the former case the big slip is above, in the latter below 14.

11. Feldspathic melaphyre 34 (34)

Amygdaloid d 13. 625 to 635

Trap d 13. 635 to 660

Specked at top and somewhat porphyritic with feldspar.

12. Feldspathic melaphyre 14 (14)

Amygdaloid d 13. 660 to 674

The bottom contact of this is marked, as often happens with the feldspathic beds, the tops are ill marked and they are more or less amygdaloidal throughout. It is quite likely that 10, 11 and 12 are all one flow. In Hole 14 we find similar beds between 14. 131 and 14. 282, and in Hole 3 beneath the heavy ophites down to 3. 673 there is a considerable interval down to 3. 891 in which no marked ophites occur. This hole seems on the whole less disturbed at this point than the others.

13. Amygdaloidal melaphyre d 13. 674 to 694

The amygdaloid is marked and seems to dip at an angle of 51.5° against the core, but this may be the effect of numerous slips at 45° to the core, probably vertical seams which seem to attend the big fissure.

14. Fissure

Extensive shearing at 45° to the core, i. e., probably about vertical.

15. Feldspathic ophite. Baltic lode and Foot?

Amygdaloid d 13. 696-698

Trap d 13. 698-744 or 748

At 701 to 704 a little copper

Dr. Hubbard's thin section at 705 ft. shows under microscope a coarser ground mass than d 3. 872 of about half plagioclase laths; about a tenth iron oxides, idiomorphic but largely secondary,

minute specks of disseminated calcite, and some filling very minute cracks, apparently not over 5%, and a few porphyritic feldspar crystals?

At 725 ft. it remains speckled and slightly porphyritic in appearance. At 731 to 4 there appears to be a faint 2 mm. mottling. At 737 it is so brecciated as to look like a conglomerate, and continues gray brecciated to 748. But this is probably not a genuine conglomerate. Conglomerate 3 may be thrown back by the fissure of Belt 4.

This may probably be continued by the section of the trenching on the east side of the N. E. ¼ of the N. W. ¼ of Sec. 14, T. 54 N., R. 34 W. which begins at the S. E. with holes in the eastern sandstone and exposed a good deal of disturbed matter and at least one fairly heavy ophite and four amygdaloid zones in some 300 or 400 ft. A black and white amygdaloid with copper float may be in the lode near which No. 13 ends.

Isle Royale drill hole 14. About 1100 ft. E. and 300 ft. N. of the S. ¼ post of Sec. 11, T. 54 N., R. 34 W. Elevation 386 A. T. Put down *about* at right angles to the strike and dip at an angle of 34°. In the pit in which it was started the overburden was in places not 5 ft. deep. It is paralleled by trenching from the S. E. corner of the S. W. of the S. E. of Sec. 11.

1. Drift 30 ft. (17)

[52]. 2. The Mabb ophite

Trap d 14. 30-131+101+ top equal (203+?)

This coarse ophite seems to be about the same in grain as that d 14. 600 to 700, which *may* be the same dropped down, or rather not thrown up so much, and appears to be the one found almost continuously, shortly above the horizon in which the Baltic lode is sought. At 76 is an amygdaloid or doleritic spots; at 115 numerous chloritic slips at 22° to the core; at 131 slips parallel and at 22° to the core, and also a white seam at less than 22° is faulted by one at 23°. This could be explained as a vertical seam striking N. thrown by a northwesterly seam with a rather flat hade to the N. There are others parallel and at 53° to it,—the latter probably nearly parallel to the dip. The grain shows at

30, 41, 62, 84 (finer), 99, 115, 127 feet ophitic mottles respectively

8, 5-7, 4-5, 5 3-4, 2-3, 1 mm. across

an average rate of increase of about 1 mm. in 13 ft.

Cf. I. R. d 3 from 673 back to 565 ft.

3. Brecciated amygdaloid and very likely slide or a little amygdaloid conglomerate d 14. 131-141 10 (10)

The breccia shades into the underlying trap, but there appears to be red and dark green fragments of sedimentary origin, epidote and calcite, in the amygdaloid.

4. Feldspathic ophite 31 (31)

Amygdaloid removed or included in the overlying bed.

Trap d 14. 141-172.

Specked, fine grained, slightly porphyritic to 151. At 152 a cal-

cite seam at 68° to the core; at 152 seams parallel and at 45° to the core; at 162 ophite 2-3 mm. mottles; at 168 1-2 mm.

In this hole there is *very little* of the feldspathic beds under the Mabb ophite prominent in No. 13. It may be that they are faulted out in Bed 3 and so the sedimentaries of the Conglomerate 3 group brought nearer.

5. Basic sandstone and conglomerate d 14. 172-180+ 8 (8+)

Well-marked at 172; at 173 pebble of black and white amygdaloid in it. A seam at 35° to the core is faulted by one perpendicular to it but parallel to the core. The bed passes at 180 into epidotic conglomeritic appearing stuff.

Cf. I. R. 3. 706 to 722.

6. Ophite 25 (25+)

Amygdaloid eroded away or merged in the seam above

Trap d 14. 180-205

Fine grained with occasional laumontite seams, reaching 1 to 2 mm. mottles at 192 ft. with seams at 31° and 53.5° against core.

7. Feldspathic melaphyre 33 (33)

Amygdaloid d 14. 205-212

Seamed at 22° to the core; epidotic at the base.

Trap d 14. 212-238

Fine grained, feldspathic looking, with seams at 11° against the core.

8. Feldspathic melaphyre Baltic lode? 44 (44)

Amygdaloid d 14. 238-249

Poor

Amygdaloidal trap d 14. 249-282

While the amygdaloid as a whole is poor looking, yet at 264 there is a prehnitic alteration of the slightly glomeroporphyritic feldspathic trap which carries a trace of copper. The seams are at 22.5° against the core. This is in feldspathic beds like d 13. 701, and is near the second amygdaloid below d 14. 172 to 180 which we have matched with I. R. d 3. 706 to 722. In No. 3 the second amygdaloid is at d 3. 790-795 which has also a little copper with which we may correlate it provisionally. This, too, is the belt upon which Section 12 shaft is sunk. It seems to bear a little copper quite persistently. It is the second amygdaloid above the first conglomerate below the Mabb ophite. This brings it about the position of the Baltic lode.

9. Amygdaloid conglomerate d 14. 282-310 28+ (28)

The sediment contact is about perpendicular to core, at 71° with it, and there are seams 31° with the core. At about 288 it changes to a decomposed bed, apparently an amygdaloid conglomerate which remains the same to 310, after which there is a good deal of trap, perhaps merely a talus block.

10. Trap? d 14. 310-328 18 (18)

Fine grained, perhaps a talus block.

11. Conglomerate d 14. 328-353+? 25 (25)

This is a clear, well-marked conglomerate, with quartz grains (333) and occasional pebbles. The dip makes an angle of 31° with the core; at 336 is a regular clay (red fluccan) and there is a mixture of trap and conglomerate with very abundant seams of red clay

which make an angle of about 49° with the core, to 348; thence to 353 is mainly conglomerate.

12? Trap d 14. 353-358 5 (5?)

At 358 is a slip parallel to the seam and another at 49° to it. It is a question whether this is a block in the conglomerate or faulted in. It is certainly not a normal succession as there are no amygdaloids and it is thin.

13. Conglomerate d 14. 358-373 15 (15)

Well-marked and with small apparently felsitic pebbles; seams at 79° to the core; the basal contact is well marked. It is probable that Belts 9 to 13 are closely allied making up the general horizon of Conglomerate No. 3,—the Baltic Conglomerate. But in such case compared with the section at Baltic a good deal has been cut out. The general position corresponds to No. 3. 879 to 891 where, however, the red fluccan represents a hiatus. No. 13 *may* be just approaching this horizon at the very bottom 738 to 747. It is near the top of I. R. d 2 where 55 to 106 corresponds roughly to d 14. 328 to 373. This is a good deal nearer to the lode I have called the Baltic lode than the Conglomerate is at the Baltic. But it must be remembered that at the Champion it is still farther away than it is at the Baltic.

14. Melaphyre 25 (25)

Amygdaloid d 14. 373-380

Marked; seamed parallel, and at 45° to the core.

Trap d 14. 380-398

Fine grained; seamed parallel, at 11° and 45° to core.

Amygdaloid d 14. 398-400 2 (2)

Red base, white amygdules dip 49°; seams at 18° to core; bedding at 71.5°; faulted by seams at 11° to the core.

15. Conglomerate d 14. 400-430? 30 (30)

At 407-409 trap black; then felsitic to 420; at 424-430 more trap; at 430 a brown rock with blotches which I take to be derived from a steam filled mud.

16. Melaphyre? 23 (23)

Amygdaloid d 14. 430-436

Trap d 14. 436-453

Brecciated until it looks like conglomerate at 443, then hard and seamed (at 53° to 48° against core).

17. Melaphyre 5? (5)

Amygdaloid d 14. 453-456

Trap d 14. 456-458

18. Ophite 56+ (60)

Amygdaloid d 14. 458-462

Amygdaloidal melaphyre d 14. 462-466

Amygdaloid d 14. 466-470

Well-marked gray and white and red.

Trap d 14. 470-514+

Seamed at 68° and 34°

The ophitic mottles are rather separate, like scattered rice grains; at 483, 497, 507 to 511 the mottles are 1–2, 2, 1 to 2 mm. respectively.

Then at 514 there is a big seam and then coarser mottling.

Evidently about 10 ft. of the base of this flow is cut off as well as the top of the next.

19.	Ophite	29	(40+)
	Amygdaloid (cut off by big fault)		
	Trap d 14. 514-543		
	At 520, 530 growing finer 2–3, 2 mm.		
	This is much seamed near 514; again at 520 at 90° and 64° with core. This is quite possibly a repetition by faulting of the lower part of 18.		
20.	Breccia or conglomerate replacing amygdaloid d 14. 543-547	4	(4)
21.	Ophite	25	(30±)
	Trap shattered d 14. 547-572		
	Brecciated at 550-555 and quite like a conglomerate in place to 569. Still veined and brecciated to 572 where it is very much seamed. Ophitic mottles in spots, at 549 1 to 2 mm.		
22.	Probably large fault repeating the series near 572	0	0
23.	Ophite (the Mabb ophite repeated?) d 14. 572-813	241	(250)

This ophite is much seamed and veined and the grain more or less irregular, but on the whole it appears as coarse as the Mabb ophite toward the center, by direct comparison. It has a redder hue due to alteration, and the patches of mottles seem more isolated, which may be due to a more extensive chloritization of the augite patches before they were oxidized. It *may* of course be some other large ophite. The mottles are:

at 578,	581,	588,	598,	(seamed and faint from 604 on),	627,	
1,	2–3,	3–5,	5+,		5–7,	
649,	668,	750,	760-783,	801 feet.		
5,	5–7,	1,	fine, seam,	2 mm. across.		

The slips make with the core an angle of 51°, etc., 74°, 60°, 35°, 31° being probably near vertical; at 588, 637, 647, 742, 783 respectively; from 604 to 627 full of red seams and brecciation; and to 660 much seamed, and especially just above 742, and about 783 feet.

24.	Conglomerate d 14. 813 to 825	12	(12)
	Marked, felsitic.		
25.	Felsitic melaphyre	41	(41)
	Amygdaloidal trap d 14. 825-827		
	Trap d 14. 827-866		
	Begins black and white amygdaloid, grows gray and coarser with less amygdaloid, grows finer from 859 down.		
26.	Felsitic melaphyre	21	(21)
	Amygdaloid d 14. 866-875		
	Marked; dark base with gray and pink laumontite		
	Trap d 14. 875-887		
	Bunches slightly glomeroporphyritic with 2 mm. bunches of feldspar. These beds seem to come under the Mabb ophite in Hole 13.		
27.	Melaphyre	17	(17)
	Amygdaloid d 14. 887 to 891		
	Heavy calcite seam at base		
	Trap d 14. 891 to 904		
	Speckled and at base brecciated and perhaps conglomerate.		

28. Breccia or conglomerate d 14. 904-951 (47±)
Looks especially conglomeritic about 914; speckled and faulted to 922; conglomerate? to 924; ophite pebbles 3 mm.; at 932 2 mm.; at 934 1 mm., and finer, full of seams, to 944 and brecciated beyond. On the whole this appears like a shattered ophite and we get spots showing 2 mm. mottles; at 949 mainly seamed; at 951 seems to be a little regular conglomerate.

29. Amygdaloid conglomerate with streaks or blocks of trap and amygdaloid d 14. 951-993 42 (42)
Amygdaloid d 14. 951-955
Trap d 14. 959-963; 969 to 971; 983 to 987.
These small streaks are either faulted in or are blocks.
Ophite d 14. 993-999 6±
The mottles are 2 mm., showing that this is a block.
From 999 to 1001 is a transition to the Eastern sandstone.

30. Eastern or Jacobsville sandstone d 14 999-1017
Dip about 45° with core from 999 to 1001; to 1004 coarse grained, mainly white, rounded quartz with few dark red or black grains also; dip against core 59°, 49° or 45°.

The Isle Royale did some work on Section 12, farther southeast along the strike, the results of which are given in Figure 45 and shown in Plate X and discussed somewhat above. I conceive that near the eastern sandstone some blocks containing the Mabb ophite have not been so much unheaved, so that we are liable to find that and the underlying Baltic horizon repeated. It is, of course, possible that faulting has brought together other similarly heavy ophites. It is also probable that the smooth and continuous curve in which Conglomerate 8 was put in on Plate X, connected by dots that show our ignorance, will be found to be broken here and there, and that these breaks become more and more pronounced near the great fault.

It will be seen from the Isle Royale cross-section (Fig. 44) that I consider the formation much distorted and sheared at the south end. In other words, I believe that as we approach the south side of the range, which is bordered by a fault that aggregates many thousand feet, we meet more and more numerous disturbances. Is there not evidence that motion in this plane took place at various times during a long interval, that the Lowest Keweenawan (the Bohemian Range group) was upheaved long before the nearly flat Freda sandstones were laid down,—indeed, before the Calumet and other felsitic conglomerates which contain pebbles of its acid intrusives? But there seems also reason to believe from the disturbed condition of Limestone Mountain, so carefully worked out by W. L. Honhold, (Fig. 47) that disturbances occurred along this line even after the Niagara, perhaps at the time of the Appalachian

revolution. Thus it is perfectly possible to find wedges of Jacobsville sandstone, as shown in the Torch Lake section, formed on the Keweenawan and at the same time overlapped by it in this later faulting.

§15. FAULTING NEAR PORTAGE LAKE (PL. X.)

The valley of Portage Lake is not itself due to faulting. It was rather carved down into the Trap range by some superimposed river which flowed across flat lying sedimentaries from the Huron Mountain boss, while gradually erosion exposed the Trap range. This implies that the Trap range, as we now have it, was once completely enveloped with sandstone or other flat lying sedimentaries, and that the lowlands of sandstone on either flank are the result of erosion. Cores and blocks of sandstone high up on the range, residues clinging to it like those which have been described by Hubbard,[1] and the sandstones and the sedimentary Trenton and Niagara limestones of Limestone Mountain both confirm this view. But Marvine describes a fault as following Portage Lake which would, on passing from the north to the south side, heave the Allouez conglomerate 710 feet[2] horizontally, at right angles to the strike, and other beds from 705 to 740 feet. Recent work at the Dacotah (South Quincy) confirms this. On the other hand, Hubbard and W. W. Stockly had made a very careful survey of the Isle Royale-Arcadian lode and as a result[3] came to the conclusion, which I think a comparison of the detailed drill section here given only confirms, that the Isle Royale and Arcadian bed were the same and that the horizonal displacement could at most be 275 feet, and that a gentle curve of only 3° 20′ in 15,000 feet would make them continuous. Now to reconcile these facts we may suppose (1) a fault of increasing throw along the lake, (2) a strike fault with a dip other than that of the beds stopping or changing the amount of displacement suddenly at a fissure near the lake, (3) a fault which as Conglomerate 8 can be followed south of Portage Lake quite continuously through Sections 1 and 36, and the Isle Royale mine levels run from Section 1 through 36 to 11, would have to run north.

There are disturbances in the Hancock mine, and the Quincy cross-cut described above has the Allouez conglomerate (15) replaced by a slide with an average steep dip of 63°, while the conglomerate which might be identified with the Houghton might also

[1]Vol. VI, Pt. II, pp. 123-124. See also map of Sec. 12, T. 54 N., R. 34 W.
[2]Vol. I, Pt. 2, p. 61.
[3]Vol. VI, Pt. II, pp. 108-109.

be the Allouez faulted back. But this would seem to be negatived by the continuity of the mine drifts unless there has been an unconscious passage from one amygdaloid horizon to another. As C. D. Lawton says in his reports as Commissioner of Mineral Statistics, the Quincy mines a belt 200 feet wide including more than one amygdaloid.

The developments in the Hancock mine in which considerable displacements may be expected will in time settle the question definitely. The Quincy mine has an apparently tight calcite parting, shown in the published mine maps, which runs from near No. 25 shaft about N. 35° W. Near this and near fissures generally the vein is leaner. The Quincy is, on. the whole, one of those "richest under high ground." There seems also to be a slide from No. 7 running more nearly east and west and dipping to the north. Whether there is a block dropped between these two back to the southeast may be a question. It is often reported to be leaner with depth and in No. 8 shaft at the north there was, at least at the beginning, more laumontite, less prehnite.

Supplementing Section XI of Volume I of these reports, we may add the following notes. The Freda sandstone is exposed not only there along the Lake Superior shore but on the hill in Section 29, T. 54 N. and R. 34 W., and it is said also in Boston Creek, Section 2 of the same town and in St. John's Creek a mile northeast. It is also found in Cole's Creek, Section 33, where it dips 12° to N. 67° W. As such dips are within the range of initial deposition dips, it is very unsafe to estimate thickness from them. There is a breadth of over seven miles which at a 12° dip would give a thickness (6,300 feet).

Then to the Atlantic stamp mill the dip probably steepens to match that on the north side,[1] for in the creek valley the sandstone dips 28° to 29° to N. 70° W. It is broken by small slips and displacements parallel to the trend of the Trap range which is more east of north. One *might* add a thickness of 4,400 x sin 28° (2,100 feet).

File 14-4 is an old section by E. J. Hurlburt, (July, 1858), of the section along the south shore of Portage Lake duplicating XI of Volume I to some extent. The distances are scaled along an east and west line. To get thickness one should multiply by (cos 33° x cos dip) or about .3. From the sandstone just mentioned to the beginning of this old section is about 1,700 feet in thickness, (800) to (1,000) feet. The numbers to the conglomerates are those of Marvine's Section 11.

[1] Which dips 24° to 29° to N. 63° 23′ W. L. L. H.

22.	"Conglomerate extent undetermined 1200 feet to west boundary"	80+		
	"Compact gray trap"	86	(26)	
21.	"Old red sandstone"	20	(6)	
	"Amygdaloid"	68	(21)	
20.	"Vein split up laumontite strings. 25 lb. copper taken out, ancient pits, stone implements on this vein and charcoal found, 1858	24	(7)	
	"Coarse gray trap granular"	132	(44)	
19.	"Old red sandstone"	18	(6)	84
	"Trap gray compact containing a heavy deposit of epidote"	126	38	
	On hanging of conglomerate "large vein epidote, spar, prehnite, and some quartz. 100 lb. copper taken out, ancient pits on this vein," June 25, 1858.			
18.	"Conglomerate"	200	60	98
	"Small vein spar, epidote, laumontite"			
	"Strings of laumontite"			
	"Coarse gray trap"	350	(105)	
	"Epidote vein"			
	"Gray compact trap resembling the overlying of rock of Pewabic lode"	350	(105)	

Next is about 620 feet from the quarter post just mentioned covered by the trenching of cross-section and including Conglomerate 17, the Hancock West. This takes us to a hole put down by the Dacotah Heights Company. This was at 45° to S. 56° W., practically at right angles to the strike, and so nearly at right angles to the dip that less than 4% correction certainly is necessary. It is 36 feet A. L. S. in the mouth of an old adit from which there is a stream. The record by A. H. Meuche follows and begins nearly where cross-section XI ends.

Dacotah Heights drill hole 1.

1. Glomeroporphyritic ophite.

No. core	d 1.	0-15.
Trap	d 1.	15-87.

The hole started above an old trench and is in foot wall of lode when they began to drill. The first fifteen feet for which there is no core probably represents the amygdaloid upon which they were trenching.

2. Glomeroporphyrite.

Amygdaloid with copper	d 1.	87 -94
Trap (Porphyrite)	d 1.	94 -97½
Amygdaloid with some sediment	d 1.	97½-98½
Trap	d 1.	98½-108.

These two beds have the characteristics of the beds immediately above the Pewabic lode. The feldspar crystals have aggregated into groups presenting to the eye a sort of mottled appearance somewhat like the ophitic mottlings except that they are not so pronounced and are whiter

in color. If well pronounced these aggregates are liable to be mistaken for amygdules. These same beds are often porphyritic and individual feldspar crystals larger than the general run of them are found not only in these cores but in specimens from other places.

3. Glomeroporphyrite.
   Amygdaloid d 1. 108-114
   Trap 114-116
   Amygdaloid 116-121
   Trap 121-126
   Beds Nos. 2 and 3 seem to be united north of Portage Lake.
4. Glomeroporphyrite.
   Amygdaloid 125-132
   Trap 132-140
   Amygdaloid (or bomb?) 140-142
   Trap 142-164
5. Glomeroporphyrite.
   Amygdaloid d 1. 164-167
   Trap d 1. 167-183
6. Glomeroporphyritic ophite. Pewabic lode and Foot.
   Amygdaloid d 1. 183 -189½
   Trap 189½-193
   Amygdaloid 193 -197
   Trap 197 -296

   The top of this flow is the Pewabic lode and is probably represented by these two amygdaloids with the intervening trap.

   Base of flow above base of Allouez Conglomerate (394)
   North of Portage Lake this distance is (379)
7. Glomeroporphyritic ophite. Old Pewabic lode and foot wall.
   Amygdaloid d 1. 296-306
   Trap 306-332
   Amygdaloid 332-336
   Trap 336-339
   Amygdaloid 339-345
   Trap d 1. 345-347
   Amygdaloid 347-350
   Trap 350-406

   Base above base of Allouez conglomerate (284)
   North of Portage Lake this is (278)
8. Ophite
   Amygdaloid d 1. 406-442
   Trap d 1. 442-526

   This is more typically ophitic than any of the beds above. The mottlings are here caused by the augite crystals. The bed is thicker here than to the north and causes somewhat of a discrepancy.

   Base above base of Allouez conglomerate (164)
   North of Portage Lake this is (249)
9. Glomeroporphyrite. Albany & Boston Amygdaloid and Foot.
   Amygdaloid d 1. 526-530
   Trap d 1. 530-567

10. Melaphyre

Amygdaloid d 1.	567-581
Trap	581-602
Amygdaloid	602-605
Trap	605-628
Amygdaloid	628-629

11. The Mesnard lode.

Sediment d 1. 629-631

Often called the St. Mary's lode or Epidote and Mesnard Epidote. An indurated volcanic ash. Around Portage Lake is epidotized and it, together with the Allouez conglomerate beneath, make one of the easiest and surest correlations which we have in the entire Keweenawan Series.

Base above base of Allouez conglomerate	(59)
North of Portage Lake this is	(90)

12. Glomeroporphyrite.

Amygdaloid d 1.	631-635
Trap d 1.	635-642

13. Ophite (?). "The Greenstone."

A series of traps and amygdaloids d 1. 642-674.

This is all that is left of that bed so famous and strong in Keweenaw County.

14. Allouez conglomerate

Conglomerate d 1. 674-690

Often called the Albany and Boston conglomerate. It often carries copper but in no place so far has there been enough copper to pay to mine. According to Marvine this is Conglomerate No. 15.

15. Ophite 4 mm.

Amygdaloid d 1.	690-696
Trap	696-700
Amygdaloid	700-712
Trap	712-714
Amygdaloid	714-720
Trap	720-725
Amygdaloid	725-730
Trap	730-734
Amygdaloid	734-737
Trap	737-795

I speak of this as a four mm. ophite because the mottlings reach a diameter of four millimeters. The size of grain of these ophites is often useful in correlating.

16. Feldspathic ophite. 4 mm.

Amygdaloid d 1.	795-806
Trap d 1.	806-863

This amygdaloid may be correlated as the Medora lode but the distance between the two points is too great to consider this as anything but a suggestion.

17. Ophite 6 mm.

Amygdaloid d 1.	863-867
Trap d 1.	867-982

If the above correlation is allowed this ophite could be called the Mandan ophite. North of Portage Lake the amygdaloidal top to this bed has been called the "Ragged Amygdaloid" by Marvine. M. G. S. Vol. I.

18. Feldspathic Trap.

Amygdaloid d 1.		982-989
Trap	d 1.	989-1007

19. Ophite.

Amygdaloid d 1.	1007-1017
Epidotic Sediment d 1.	1017-1020
Trap	1020-1060

It will be noticed that Meuche, and I think he is right, places the Allouez at 690 feet which would correspond to about 250 feet horizontally across the strike, and would bring it nearly in line with what *has* been called the Houghton conglomerate in the Quincy adit. The Mesnard at 630 would be thrown 790 feet over. The Pewabic lode at 189 would be thrown 235 feet over.

§16. ATLANTIC (PL. X AND FIGS. 46 AND 47.)[1]

The collapse of the shaft on the old Atlantic lode some time ago has caused them to give considerable attention to explorations, both in their land on Section 9 and Section 16, T. 54 N., R. 34 W. In Section 9 continuous trenching was carried out (as shown on Plate X and Figure 46) with special eye to the Quincy lodes.

At 483 feet a conglomerate has been struck in two places, Hubbard's Conglomerate B.

At 830 feet from the Atlantic foot was a heavy trap. Cf. Tamarack 5 belt 20.

At 849 Amygdaloid for a few feet.

At 865 was near the center of the next trap, the rock at 879 feet was like Sp. 16413 close above Conglomerate 16.

At 879-890 was an amygdaloid with copper (one of the Hancock lodes?)

At 913 was trap. Cf. Sp. 15304.

At 935 was amygdaloid of the Ashbed type.

At 963 was a trap, a porphyrite of the Ashbed type.

At 997 was an amygdaloid with copper. I take it that the next 200 feet are the horizon of the Quincy mine.

At 1012 was a slightly sedimentary top of a flow which extends to 1040. Cf. Tamarack 4b 28 and Sp. 16428 and 16429.

At 1040 to 1085 A there was amygdaloidal porphyrite. Cf. Sp. 15351.

At 1115-1133 was a marked basal trap.

At 1133-1161 was a coarse amygdaloid like some of that at the Quincy.

At 1161-1179 was trap, coarse, massive, feldspathic and chloritic, like that which occurs around the Quincy mine, cf. 16416 A.

At 1179-1194 was amygdaloid. Then trap, at 1225 coarsely feldspathic and chloritic.

At 1232-1234 was two feet of amygdaloid. Cf. Sp. 16413. Then trap of the ashbed type still, oligoclase porphyrite. Then a coarse,. doleritic trap.

At 1465-1482 is amygdaloid. (Cf. in the Franklin Junior the heavy amygdaloid belt 100 to 150 feet above the Mesnard). Then another trap.

At 1605 is, I think, the Mesnard epidote, a few feet shading into amygdaloid. Just underneath is a well-marked ophite, not very thick, the first marked ophite and so, I think, the last edge of the "Greenstone" to 1650.

From 1650 to 1675 is a conglomerate which would then be the Allouez (No. 15).

At about 1850 is an amygdaloid with below it a well-marked ophite with 3 to 5 mm. mottles. (Cf. the Mandan ophite.)

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[1]Plate X and Fig. 47 are in envelope. The Atlantic Mine is now consolidated with the "Copper Range" companies.

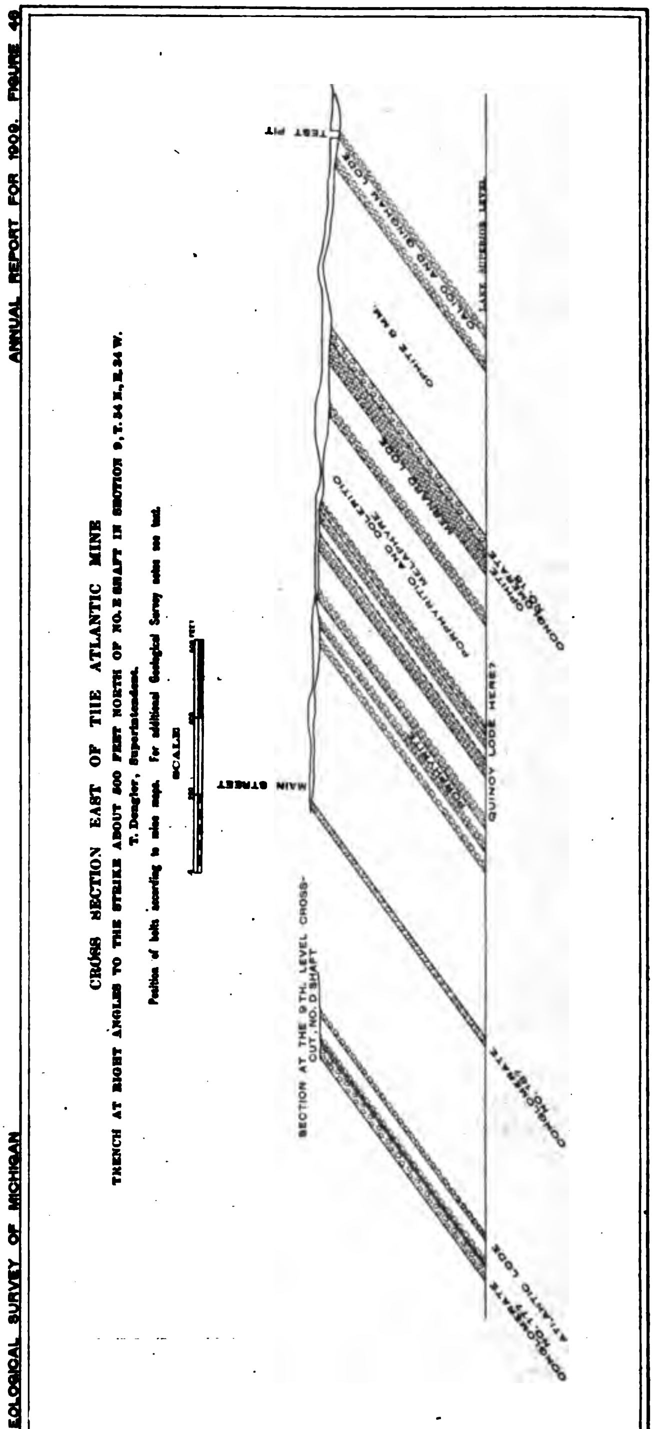

Fig. 46. Atlantic mining explorations on Section 9, T. 54, R. 34.

From 2200 to 2250 are brilliantly colored brecciated red and green (epidote) and white (calcite) amygdaloids or amygdaloid conglomerates, so-called "calico" lodes, much like stuff that commonly occurs near the horizon of the Houghton conglomerate and Montreal lodes. The character of the associated traps (not known to Hubbard when he wrote Volume VI) leads me to be pretty sure that the conglomerate at 1650 feet is the Allouez, No. 15. The Mesnard is also a characteristic bed, The one at 483 feet would, then, be about (1000) feet in thickness above it, and Conglomerate A, close above the mine, (the splitting off of a great block of the hanging wall along this conglomerate closed up the mine) is (468) higher yet, and the three will be 15, 16 and 17, a correlation to which Hubbard calls attention in a foot note.

It is clear that the beds of Section IX of Volume I and those exposed on the Dacotah property near where the Copper Range crosses the Highway are above the "Mesnard Epidote" and are in the Ashbed group and not far from the beds mined in the Quincy mine. Swinging them in as indicated on Plate X would necessitate a fault of not over 300 feet.

About 2000 feet from this Houghton (?) conglomerate at the end of Section 9 trench would pass a strike line connecting a marked conglomerate on Section 2 with one (dip 55° to 60° to N. 32° W.) about 1300 paces north, 300 west of the northeast quarter of Section 17. The associated rocks are similar to rocks southwest from it near the foot of Wheal Kate, beautifully skeined and banded with amygdaloid seams, rather feldspathic, with a dip of 60°-70° to N. 38° W., say (2560) feet from or (2100) feet below what I take to be the Allouez as against (1942) for the Kearsarge-North Star at the Arcadian.

About 200 paces south begins the S. Range drilling (Fig. 47) and while Hole No. 4 (the southernmost) cuts Conglomerate 8 to 6, the others do not, so that we may feel confident that this conglomerate is either 9 or the group 10 to 12, the Kearsarge. Farther south at the Winona we found a number of sedimentary beds at about this horizon. I think, therefore, we may safely call it the Kearsarge as that is stronger and more of a felsitic conglomerate, and less of a sandstone than No. 9.

The Kearsarge lode and Wolverine sandstone horizon is then untested. The rest of the section to the Atlantic cross-cut on Section 16 is covered by the South Range holes. The following are the engineer's notes of location. (See map).

From this conglomerate hanging it is 5626.87 feet to the Baltic 0, and 5767 feet from the hanging of Conglomerate 3 which is 97.56 feet from the Baltic 0.

No. 5, South Range is 5368.49 feet from Baltic outcrop and lode. Elevation 529.3 A. L. S. Dip 44° 41′

No. 3 4458.51 N. W. of Baltic 0	El. 418.7 A. L. S.	Dip 45° 11′
No. 1 3581.38 N. W. of Baltic 0	513.1	Dip 46° 26′
No. 2 3546.02 N. W. of Baltic 0		Dip 60°
No. 4 2858.44 N. W. of Baltic 0		Dip 46° 24′

The detailed records have been used in constructing Fig. 47. (It will be noticed that with a dip of hole of 46° and a dip of strata of 68° the distances along the hole and horizontal will be the same).

The ground intervening is 3 and 10 is drift covered and does not belong to the Atlantic Mining Company, so that they take up the section again in Section 16. Unfortunately their work there is so close to a cross-fault that it is seriously disturbed and down to the 21st level they did not find the lode valuable or settled. (See Plate X).

The South Range is the only section I know of that is complete above Conglomerate 8, but below there are a number. There is a mass of notes on trenches on Isle Royale and Superior, but they show more or less faulting and are disturbed

and incomplete. Underground we have the Atlantic Section 16 cross-cut, Fig. 47 notes of which follow.

Atlantic mine cross-cut (Fig. 47 and Pl. X) Section 16, T. 54 N., R. 34 W., running N. 43° 16′ W. to S. 41° 27′ E. Elevation of collar 331 A. T. East cross-cut 52′ lower; west cross-cut 609′ lower.

Beginning at the north end, the distances are mainly scaled from the Superintendent, T. Dengler's diagram. The descriptions are from a naked eye examination of the specimens he took, and also from my own visit (Aug. 13, 1898) and examination and specimens from 175 feet northwest of the shaft to 460 feet southeast. The thicknesses are obtained from[1] the widths by multiplying by sin 59° 45′=.86.

The thickening should also be reduced by an amount depending on how much the strike differs from being at right angles to the lode. It is east of northeast. If we take the strike of Conglomerate 6 71° E. of N., and of the cross-cut N. 45° W., the angle is 66°, and the drifts run in the north part of the cross-cut indicate some such difference. If we take the strike of the Baltic lode N. 65° E, and that of the cross-cut N. 41° 16′ W., the angle will be 74°. We shall then have to multiply the thicknesses given by .9 or .96 to get a truer thickness.

1. Trap 1846-1810=36+ (31+)

   Stopped at 1846 feet of "West drift" 12:24:1902 on account of large stream of water.

   Amygdaloid 1810-1795=15 (13)

   A. S. 21, rather feldspathic, not amygdaloid.

   A. S. 22, Trap. Ophite 1795-1749=46 (39) (83)

2. Amygdaloid conglomerate 1749-1727=22 (19) (102+)

   A. S. 21, with gray-brown clasolitic material imbedding dark angular fragments.

3. Ophite (should include part of 2?) ?

   A. S. 21, A. S. 20. Trap 1727-1596-131 (112)

4. Ophite (89)

   Amygdaloid 1596-1581=15 (13)

   A. S. 20, poor red and white amygdaloid between decomposed ophite.

   Trap 1581-1502½=78½ (76)

5. Conglomerate 6. 1502½-1479=23½ (20)

   A. S. Belt 19 and No. 6 conglomerate shows rounded basic and felsitic pebbles, with a green chloritic and epidotic matrix and calcareous seam underlain by a crushed amygdaloid. This also appears in the railroad cut and the conglomerate and underlying amygdaloid which has a birdseye texture are similar.

   Base below beginning of section (211)

6. Ophite. (50)

   Amygdaloid 1479-1468=11 (9)

   A. S. 19, crushed amygdaloid, red and white, fine grained, sheared into birdseyes 1-2 mm. across.

   Trap 1468-1420=48 (41)

7. Ophite. (224)

   Amygdaloid 1420-1401.7=18.3 (15½)

   A. S. 18, fresh, clear, maroon and white amygdaloid, not crushed.

   The same horizon seems to appear back of the church and Baltic hotel.

   Trap 1401.7-1157=244.7 (208)

[1]The strike is supposed to be at right angles to the adit which is from S. 44° E. to S. 48° E. in direction.

8. Ophite. (133)

Amygdaloid 1157-1139=18 (15)

A. S. 17. Poor amygdaloid here.

Trap 1139-1000=139 (118)

A. S. 17. Foot of above, ophite with chlorite and calcite seams.

Base below base of conglomerate 6 (407) to (366)

9. Ophite. (158)

Amygdaloid 1000-980=20 (17)

A. S. 16. A crushed and brecciated, red and white amygdaloid, with some copper so that a drift was run on it southwest some 200 feet.

Trap 980-814=166 (141)

Foot of A. S. 16 is an ophite, also hanging of A. S. 15.

10. Ophite. (137)

Amygdaloid 814-788=26 (22)

A. S. 15. Coarse gray and white amygdaloid.

Trap 788-653=135 (115)

Foot of A. S. 15 is an ophite, also hanging of 11.

11. Amygdaloidal conglomerate 653-643 (9)

Conglomerate with fine red sediment as cement. Hanging and foot are ophites. Cf. at the Baltic location the amygdaloidal conglomerate on the knob 4 lots south of 2nd street on 10th Ave., and 2 lots S. of Stanton on 15th Ave. This may be near the horizon of Conglomerate 4. Total from base of conglomerate 6, 1479-643=836 (711)

or multiplying by .9 (640 feet).

12. (68)

Amygdaloid?	643-633=10	(9)
Trap	633-563=70	(60)

S. 14 ophite.

13. (84)

Amygdaloid 563-542=21 (18)

S. 13. Massive, fissured, compact, only slightly amygdaloid.

Trap 542-464=78 (66)

14. (122)

Amygdaloid 464-454=10 (9)

S. 12. Red and white (prehnite, calcite, laumontite) amygdaloid.

There was a drift southwest on this belt for about 400 feet. It was decomposed and full of laumontite seams.

Trap 454-321=133 (113)

S. with "Cong. 4" hanging of the same,—an ophite.

15. Conglomerate 321-299=22 (19)

This seems to correspond to an amygdaloid conglomerate on 2nd street at Baltic, just east of 15th street, which is about 1100 feet from and about 1000 feet below Conglomerate 6.

Marvine's Conglomerate 4 is not more than 560 feet below Conglomerate 6 and probably is represented by some of the higher belts. The Baltic sandstone and the amygdaloid conglomerate on top of the next ophite seem to correspond to amygdaloids A. S. 17 and A. S. 16. The drift on S. 16 indicates this strongly. The top of A. S. 17 is (274) to (250) feet below Conglomerate 6, while Conglomerate 5 is only (290). I should therefore be inclined to identify the "Baltic sandstone" with Conglomerate 5, which is only an amygdaloid conglomerate.

The top of Belt 10, A. S. 16, is at about the same distance from Con-

glomerate 6 as Conglomerate 4 (540 feet), which is described by Marvine (II b p. 65 of Vol. I) as perhaps amygdaloid, "strongly resembling a conglomerate or breccia of altered trap pebbles." About 144 feet below it (684 feet) he describes an "amygdaloid ? with brown porous portions surrounded by a yellow sandy material" which is an amygdaloid conglomerate and is perhaps the correlative of 11. Neither Conglomerate 4 or 5 are marked horizons as distinguished from the tops of many of these flows. Then this Belt 15, which Dengler naturally in drifting up from near Conglomerate 3 at first called "Conglomerate 4," may find its match in 147 feet "covered" just above the Mabb ophite, in which case Belt 16 would be the Mabb ophite and the Baltic lode be only a short distance below, say at 143 or 209 in the east cross-cut. This is a quite possible correlation, but would bring the lode as much too near as the correlation adopted does too far from Conglomerate 6, and Belt 16 is not as coarsely mottled as the Mabb ophite.

"Cong. 4" has round felsitic or basic pebbles and epidotic cement.

16. A large ophite. The Mabb ophite?

299-53 W 0-85 E=321	(274)	
Base below base of 11		(293)
" " " " Conglomerate 6		(1005)

Belt 11½. Epidote and amygdaloid directly under the conglomerate at 270. I examined these on the first level to 175 feet taking samples every 25 feet to 175 inclusive, Ss. 17884-17878. From 75-125 it is seamed so that the mottling is obscure but at Sp. 17879 is 4 mm. + and 17885 at 0 is 3 mm. +. Also going S. 17886 is 2 mm. and there is no marked belt until 90′ south.

Apparently 0 in this level corresponds to 53 in the level below.

In Dengler's samples there is some confusion. 0 on west cross-cut is a well-defined amygdaloid. No. 6 (sic 0?) belt at foot of shaft is not an amygdaloid but probably a much shattered ophite 2-3 mm. coarse.

Dengler also says that in the second level the amygdaloid from 85-137 feet southeast of the shaft does not appear.

There was also a drift southeast (near No. 3 plug) about 200 northwest of the shaft in the second level. In the sample bag is a genuine maroon amygdaloid, a 1-2 mm. ophite, and a 5 mm. decomposed ophite like that of the level above, where no amygdaloid was noted at this level. According to Dengler there was a seam of sandstone with a black "foot" trap, and a "hanging" mottled with chlorite, while at 175 feet from Plug 2, i. e., 183 feet in the level the trap is gray. Judging by my own notes and samples I should make but one somewhat sheared belt from 299 E. to 85 W., with a thickness not far from 300 feet, except for the mottling which does not appear to be over 5 mm. If there are two belts they are either repeated or a piece is cut out at the shearing zone. It seems quite possible in view of the sudden change from the steep dip at the Baltic to relatively flatter dips and a section extending farther southeast, while at the same time there are numerous veins and fissures in the cross-cut running as steep as 70° to 80° that there should be slide faulting producing repetition here, or possibly producing erosion of part of the section at the Baltic.

17. Amygdaloid conglomerate (99)

Amygdaloid 85-137 and ophite 52 (44)

I made it 90-142 measuring from a little different starting point.

S. 1. Fine grained dark trap, and dark amygdaloid with chalky white blotches of decomposed prehnite, like the Isle Royale Sec. 12 shaft, also maroon, very amygdaloid fragments in a calcitic matrix. Heavy brecciated amygdaloid, like a bed just above the Baltic lode.

Sp. 17889 at 100 is slightly brecciated, and amygdaloidal.

Sp. 17890 at 125 is much more so.

Trap 137-201=64 (55)

About 10′ below the top is a seam with a little copper[1] and at 150 it is still fine grained and porphyritic in a minute way. At 175 (Ss. 17891, 17892) the ophitic mottles are 3-5 mm. At 200 (Sp. 17893) there are small chlorite amygdules, but the mottling is still 2-4 mm., and there does not appear to be a top contact or new flow.

18. Ophite. (37)

Amygdaloid 201-208=7 (6)

"Belt 2" is a coarse red and white amygdaloid, which must be some other I think. "2 hanging at 201′ E. of Shaft 7 feet" has a purplish base and *sparse* fairly large, (20 mm. at times) chlorite or chlorite and calcite amygdules. A little copper was found in this. This is nowhere near as marked as the belt above. Sp. 17894 at 204, however, shows a marked amygdaloid with a fine grained maroon base and greenish amygdules of altered prehnite.

Trap 208-244=36 (31)

Sp. 17895 at 225 shows 2-3 mm. mottles, with calcite veins.

19. Ophite. (80)

Amygdaloid 244-282=38 (32)

(The strike line of the Baltic mine crosses the foot of this amygdaloid, the breadth allowed on the mine plan is rather generous; at 275 it is trap).

S. 3 and Sp. 17896 at 250 feet represent this. A well-marked maroon amygdaloid, *not notably* crushed, greenish amygdules with calcite and with white kaolinic matter (? decomposed prehnite).

Trap 282-339=57 (48½) represented by

Sp. 17897 at 275, a massive faint ophite, with a mottling perhaps 1-2 mm.

Sp. 17878 at 300, a massive trap blotched with a few coarse pink, green or calcite amygdules.

Sp. 17899 at 325, massive,—a 2 mm. ophite.

20. Ophite. (76)

Amygdaloid 339-359=20 (17)

S. 4 fine grained, brown with coarse large amygdules, and much greenish to white altered prehnite.

Trap 359-428=69 (59) represented by

Sp. 17943 at 375 (at 385 is a nearly vertical seam) a massive, fine grained ophite.

Sp. 17944 at 414 is a massive 2-3 mm. ophite.

21. Ophite. (137)

Amygdaloid 428-455=27 (23)

S. 5 shows well-marked amygdaloid, purplish with greenish and white amygdules, also an ophite 3 x 1 mm., this belt being taken too wide.

At 419 is a streak of amygdaloid and at 437 to 454 is a broken amygdaloid.

Sp. 17945 at 444 is fine grained and full of little chlorite blotches.

Trap 455-588=133 (114) represented by 17946

Sp. 17946 at 460 is a 1-2 mm. ophite.

[1]The tendency of copper to occur in the foot of the Baltic lode is marked.

22. (37)
Amygdaloid 588-619=31 (26)
Trap 619-632=13 (11)
S. 6.
23. The Mabb ophite? (205)
Amygdaloid 632-653=23 (19½)
Trap 655-873=218 (185)
S. 7. Very well marked amygdaloid, with many soft greenish (altered prehnite?) kaolinic amygdules.
Base of this below base of Conglomerate 6 (1950) to (1760)
24. Ophite. (61)
Amygdaloid 873-893=20 (17)
Trap 893-945=52 (44)
S. 8. Maroon amygdaloid and ophite.
25. Ophite. (67)
Amygdaloid 945-974=29 (25)
S. 9. Found a small mass of copper above this.
Dip 59°½±. Sample fine grained epidote, with some quartz epidote copper vein, and also fine grained ophite. This may be the Baltic lode.

Trap 974-1024=50 (43)
26.
Amygdaloid 1024-1051=27 (23)
S. 10. Purplish with minute, flesh colored or coarser amygdules, or with few chloritic amygdules.
27. Conglomerate 3. 1051-1056=5 (4)

Base below base of 7 mm. ophite (155)
" " " " Conglomerate 6 (2105)
28.
Amygdaloid 1056-1066=10 (9)
S. 11 (or is it 2) a maroon amygdaloid.
29. Trap 1066-1080=14 (12)
Direction at end S. 41° 27′ E., and the beds strike more nearly E. & W., say N. 55° E.

§17. BALTIC.

Leaving the Atlantic section we find on the Baltic (File 13.31) a series of amygdaloid conglomerates and ophites which can be pretty well paralleled with those in the long cross-cut, and directly continues the South Range section. We also find very heavy trap a short distance above the Baltic lode and on the whole a fairly complete section (Pl. X). The numbers in parenthesis are corrected perpendicular distances from No. 6.

Conglomerate 6, north side of Stanton Street between 11 and 12. 525 A. L. S.
6.[1] Fine grained ophite (50) (50)

[1]These numbers refer to the belts of the Atlantic cross-cut above.

7.	Clasolitic amygdaloid south side of Stanton and in railroad-cut in trenches northwest of church and on 13th Street.	11	
	Ophite 5 mm.	239	(300)
8.	"Baltic sandstone,"—an amygdaloid conglomerate with much red sandy matrix	40	
	Ophite 2 mm.	90	(430)
9.	Amygdaloid conglomerate	20	
	Ophite 4 mm. Perhaps two flows. First 60 feet exposed on 14th Street	190	(540)
10.	Amygdaloid brecciated, third lot south on 13th St	30	
	Ophite 5-7 mm.	170	(740)
11.	Amygdaloid conglomerate; knob on 10th St.; 50 feet north of corner of 2nd and 13th St.; and lot south of Stanton on 15th St. A strong belt.	33 to 50	(765?)
		50	(840)
	Ophite 3 mm.		
12.	Amygdaloid brecciated. Close to school house	20	
	Ophite 100 feet south of 2nd on 13th St., and southwest of school house, green blotched fine grained bed, perhaps three flows	270	(1130)
15.	Amygdaloid conglomerate. On 2nd between 15th and 16th Sts.; shows irregular bottom contact and width.	10 to 30.	
	Ophite 6 to 7 mm.	270	(1420)
	Amygdaloid conglomerate	20	
16.	Mabb ophite 7 mm. In front of Mine office, about 250 feet above Baltic lode;	200	(1620)
	70 feet of it with banded lines of flow.		
	Amygdaloid. Corner of 14th and 3rd Sts., skeins are chloritic and red	20	
	Trap skeined and banded	54	(1700)
	Amygdaloid black and white; elevation near No. 3 shaft 470 A. L. S.	50	
	Ophite skeined and banded	55	(1805)
	Baltic lode?	40	
	Baltic foot	160 + 90	(1960)
	Baltic conglomerate	4	(1964)

It will be noticed that the copper occurs between a heavy impervious bed—the Mabb ophite—and an open pervious water bearing one—the Baltic or No. 3 Conglomerate, like the Medora lode and various occurrences just below the Greenstone, and the lode at the Lake. This section has importance in comparisons as this lode has been much sought of late.